A HANDBOOK FOR SANITARY LANDFILLS IN FLORIDA

SUPPLEMENT TO:

SOLID WASTE MANAGEMENT PLAN FOR FLORIDA

A HANDBOOK FOR SANITARY LANDFILLS

IN

FLORIDA

DEPARTMENT OF HEALTH AND REHABILITATIVE SERVICES
DIVISION OF HEALTH
Jacksonville, Florida

The preparation of this planning document was financially assisted through a Federal Grant #G05-EC-00025-04 from the Environmental Protection Agency, Solid Waste Management Office authorized by Section 206 of the Solid Waste Disposal Act of 1965.

STATE OF FLORIDA
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BUREAU OF SANITARY ENGINEERING
Sidney A. Berkowitz, M.S.E., Chief
Nick Mastro, M.P.H., Assistant Chief

Project Director
J. Benton Druse, M.S., Supervisor
SOLID WASTE PLANNING

Project Staff - Michael D. Harley, B.S.
Lauren P. Tuttle, C.E.

ACKNOWLEDGEMENTS:

We appreciate the special assistance and encouragement from the following individuals:

Division of Health
Bureau of Entomology
John P. Mulrennan, B.S.A., Chief
Ernest A. Philen, C.E., M.P.H.

Administration
Robert A. Schoonover, Health Educator

Department of Pollution Control
Divison of Planning
W. E. Starnes, B.S. Ch. E.

Division of Operations
Bureau of Permitting
W. E. Linne, Acting Chief

Department of Natural Resources
Bureau of Geology
J. William Yon, Jr., Geologist
B. E. Lane, Geologist

United States Geological Survey
Water Resources Division
Joseph W. Stewart, B.S.E.M., Hydrologist

United States Department of Agriculture
Farmers Home Administration
Claude L. Greene, Jr., State Director

United States Department of Housing and Urban Development
Planning and Relocation Branch
Roger A. Swanson, Assistant Director

Charlotte County Health Department
S. W. Andrews, Sanitation Director

Manatee County Anti-Mosquito District
Lawrence M. Rhodes, Director

Marion County Health Department
Gene M. Price, R.S., Sanitation Director

Martin County Anti-Mosquito District
Lester E. Scherer, Director

Polk County Mosquito Control Department
Frank L. Wilson, Director

Polk County Board of County Commissioners
Jack Simmers, Chairman, Environmental Services Committee

Sarasota County Health Department
Fred H, Heinzman, P.E., Sanitary Engineer

City of Jacksonville, Florida
Clinton W. Brown, Chief, Sanitation Division

County and City Health Departments
Public Works Officials

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INTRODUCTION

Solid wastes may in general be divided into two classifications: (1) material which is organic and putrescible, and (2) inorganic materials. Improper disposal of the putrescible organic materials, including certain inorganic chemicals and metals, can create public health problems.

Organic and inorganic wastes in Florida are, with a few exceptions, disposed of in landfills. Unless these landfills are properly designed and operated, the disposal site can contaminate surface and/or underground water supplies; pollute the air with objectionable odors, including smoke when burning is not prevented; produce flies, mosquitoes, and rodents; and depreciate the value of nearby real estate.

The purpose of this handbook is to serve as a guide in planning for the disposal of solid wastes in Florida by the sanitary landfill method.

I. PLANNING

THE NEED

The rapid growth of Florida has created increasingly serious insults to the environment due to past failures to provide the necessary advance planning and land management programs (zoning), particularly in the field of solid waste disposal. No longer can the public afford to ignore the increasing environmental imbalance created by the improper solid waste disposal methods being practiced in many areas of the State.

DEFINITIONS

The fact that solid waste, even after processing by incineration, composting or some other method, must be disposed of in a sanitary landfill makes it essential to know what one is. There are two definitions which can provide a basic understanding of the method. The American Society of Civil Engineers definition reads:

> "Sanitary landfill is a method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary."[1]

The Office of Solid Waste Management Programs of the U.S. Environmental Protection Agency (EPA) defines a sanitary landfill in the following manner:

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[1] Solid Waste Systems Planning, Office of Solid Waste Management Programs, U.S. EPA, Cincinnati, Ohio, Sanitary Landfill I, 1972, page 1.

"A sanitary landfill can be defined as a system for the final disposal of solid wastes on land, in which the waste is spread and compacted on an inclined, minimized working face in a series of cells and a daily cover of earth is provided so that no hazard or insult to the environment results."[2]

This method of solid waste disposal is not only aimed at better protection of the public health, but toward making solid waste disposal more acceptable to the public.

REGIONAL APPROACH

Regional, county and intermunicipal co-operation in the management of solid waste has many advantages to offer the people living in these areas. The operation of one or more centralized disposal areas permits better solid waste handling and disposal, often using fewer supervisors, personnel and equipment. Central sites of adequate size cost less per acre to purchase, and the operating cost per ton is usually lower than for several small sites. Figure I illustrates some of the economies of a regional concept.

The regional approach provides an opportunity for the creation of a large well organized solid waste agency, capable of acquiring necessary land (five years in advance of the need and with an anticipated life of up to 20 years) handling present and future disposal systems, long range planning, maintaining inflexible zoning in the present and proposed disposal site areas, and maintaining control of operational efficiency through a cost accounting system.

Any regional approach must include a cost accounting system to permit an accurate assessment of all phases of the operation and to pinpoint any problem areas. Cost accounting collects data on each

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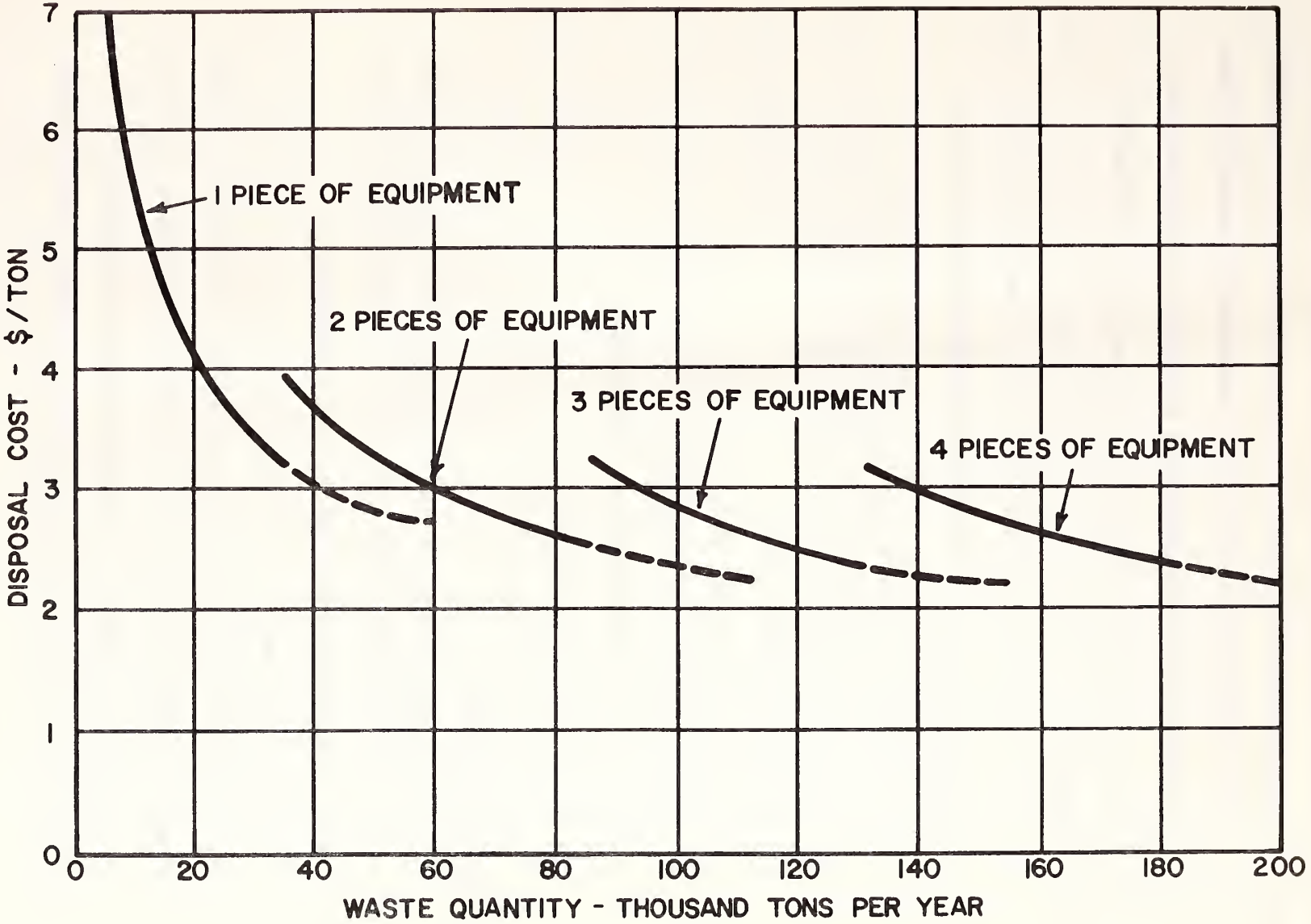
[2] Op. Cit., Page 1.

FIGURE 1
SANITARY LANDFILL COSTS



This graph was developed by Malcom Pirnie, Inc. The dashed portions of the curve indicate overtime or second shifts allowing the site to be operated without purchasing additional equipment.

phase of the operation such as cost, time required, and quantities handled; and groups this information in standard accounting classifications. This permits those with actual management responsibilities to know the cost and efficiency of each part of an operation. The following records should be kept to provide adequate information for such a system:

A. Daily quantities, sources, and types of waste received.

B. Daily quantities of cover material received from outside sources, if any.

C. Weekly labor report listed by individual employees.

D. Monthly maintenance cost for each piece of equipment.

E. Landfill equipment cost.

F. Landfill facilities cost.

G. Total operating cost statement.

H. Total calculated depreciation statement.

I. Total cost of entire system.

PLANNING OPERATIONS

The collective thinking of government agencies (federal, state and local), industry and citizens should be considered in the development of an acceptable plan for solid waste disposal.

Planning should begin with a survey and analysis of the facts related to the immediate and future solid waste management problems. The effective development of a plan from this information requires that every practical means of disposal and its associated cost be considered for a study area. Planning considerations must include

not only the physical features of each individual proposed site and its proximity to the service area, but also how the site will fit in with state, regional, county and municipal plans for solid waste disposal and land use. A completed plan should contain enough information to enable the appropriate public officials to make the necessary decisions.

Once the necessary decisions have been made, the most suitable site of those proposed should be selected, followed by detailed engineering plans, specifications and construction.

FINANCIAL ASSISTANCE

Financial assistance for the planning and/or the construction of solid waste disposal facilities is available from both federal and state agencies. This assistance may take the form of grants, loans or credit backing.

I. Department of Housing and Urban Development (HUD) (as taken from HUD Programs, U.S. Department of Housing and Urban Development, Washington, D.C., 1969).

Contact the HUD Florida Area Office, 661 Riverside Avenue Jacksonville, Florida 32204 for further information.

A. Advance Acquisition of Land (Section 704-HUD Act of 1965)

Grants are made in amounts not to exceed the reasonable interest costs involved in financing the acquisition of land for a period of up to five years in advance of its use for approved public purposes. In unusual circumstances, HUD may allow for more than five years. The approved use of the land must be consistent with the comprehensively planned development of the area.

B. Open Space Land (Title VII, Housing Act of 1961)

Grants of up to 50 percent of costs in acquiring land for open space use, and further grants of up to 50 percent of improvement costs for developing the land are made. Acquisition and development of open space land must be in accord with local and areawide comprehensive planning. A grant to acquire developed land in a built-up urban area may be made only if there is no suitable undeveloped land in the same area.

Acquisition costs include costs for acquiring land and certain structures, demolition of inappropriate structures, and real estate services. Improvement costs include costs for basic facilities, such as roadways, signs, landscaping, and other items, but not costs for major construction.

C. Public Faciliites (Title II, Housing Amendments of 1955)

Loans for up to 40 years and covering up to 100 percent of project cost are made for use in financing a variety of public works projects - construction of water and sewage facilities. Loan aid under this program is available only for those parts of a project not covered by aid provided under other Federal agency programs. Priority is given to applications of smaller communities for assistance in construction of basic public works.

D. Comprehensive Planning Assistance (Section 701, Housing Act of 1954)

Grants of up to two-thirds (three fourths, in some instances) of the cost of a planning project are made to supplement State and local funds for comprehensive planning for areas having common or related problems.

Eligible activities include the preparation of development plans, policies, and strategies; implementation measures; and the coordination of related plans and activities being carried on at various levels of government. A broad range of subjects may be addressed in the course of the comprehensive plannning process. They include land development patterns, physical facility needs, such as housing, transportation planning, recreation and community facilities, the development of human resources, and the development and protection of natural resources.

E. Planned Areawide Development (Title II, Demonstration Cities and Metropolitan Development Act of 1966)

Grants of up to 20 percent of project costs are authorized to supplement Federal grants made under any of ten other Federal grants programs for the following types of projects: basic water and sewer facilities, libraries, hospitals, and medical facilities, sewage treatment works, highways, airport equipment, acquisition and development of land for open space, urban beautification and improvement, historic perservation, acquisition and development of lands and waters for recreational purposes, and public works facilities in redevelopment areas. The total Federal contribution may not exceed 80 percent of project costs.

II. Farmers Home Administration (Data supplied by Claude L. Greene, Jr., State Director - Farmers Home Administration)

The Farmers Home Administration (FHA) is authorized to assist public bodies in rural areas with both loan and grant funds to develop solid waste collection and disposal facilities. Grants usually cannot exceed twenty (20) percent of development cost of the project. Eligible

purposes include the collection, treatment or disposal of human, animal, agricultural and other waste, including such items as garbage trucks and equipment, sanitary landfills, non-polluting incinerators and necessary legal and engineering fees.

In order to be eligible for financial assistance from FHA, the solid waste facility must primarily serve farmers and other rural residents. This does not preclude a joint rural urban solid waste disposal facility, providing FHA loan and grant funds are used only for the rural portion. In this manner, both groups can use common solid waste facilities and can take advantage of the efficiencies involved in areawide planning.

FHA loans for solid waste facilities may be amortized over a period not to exceed 40 years. However, loans must not be scheduled for repayment over a period exceeding the life of the facility or the equipment financed. The current interest rate is five percent on the outstanding principal indebtedness.

Applications for loan or grant funds should be made on Standard Form SF 101 Preliminary Application for Requesting Federal Assistance for Public Works and Facility-Type Projects. Applications and further information should be obtained from the nearest FHA office or by contacting the State Director, Farmers Home Administration, P. O. Box 1088, Gainesville, Florida 32601.

III. U.S. Environmental Protection Agency

The Resource Recovery Act of 1970 may provide grants of up to three-fourths for planning, demonstration of resource recovery systems,

and training. The demonstrations are required to have national significance. Planning grants are required to give assurance of action. Due to inadequate funding as well as stringent requirements, few projects have been approved.

IV. State of Florida (As copied from Constitution of the State of Florida, Article VII - Finance and Taxation - Sect. 14)

Section 14 - Bonds for pollution control and abatement facilities -

(a) When authorized by law, state bonds pledging the full faith and credit of the state may be issued without an election to finance the construction of air and water pollution control and abatement and solid waste disposal facilities (Herein referred to as "facilities") to be operated by any municipality, county, district or authority, or any agency thereof (herein referred to as "local governmental agencies") or by any agency of the State of Florida. Such bonds shall be payable primarily from all or any part of revenues to be derived from operation of such facilities, special assessments, rentals to be received under lease-purchase agreements herein provided for, any other revenues that may be legally available for such purpose, including revenues from other facilities, or any combination thereof (herein collectively referred to as "pledged revenues"), and shall be additionally secured by the full faith and credit of the State of Florida.

(b) No such bonds shall be issued unless a state fiscal agency created by law, has made a determination that in no state fiscal year will the debt service requirements of the bonds proposed to be issued and all other bonds secured by the pledged revenues exceed seventy-five percent of the pledged revenues.

(c) The state may lease any of such facilities to any local governmental agency, under lease-purchase agreements for such periods and under such other terms and conditions as may be mutually agreed upon. The local governmental agencies may pledge the revenues derived from such leased facilities or any other available funds for the payment of rentals thereunder; and, in addition, the full faith and credit and taxing power of such local governmental agencies may be pledged for the payment of such rentals without any election of freeholder electors or qualified electors.

(d) The state may also issue such bonds for the purpose of loaning money to local governmental agencies, for the construction of such facilities to be owned or operated by any of such local governmental agencies. Such loans shall bear interest at not more than one-half of one percent per annum greater than the last preceding issue of state bonds pursuant to this section, shall be secured by the pledged revenues, and may be additionally secured by the full faith and credit of the local governmental agencies.

(e) The total outstanding principal of state bonds issued pursuant to this Section 14 shall never exceed fifty percent of the total tax revenues of the state for the two preceding fiscal years.

In Florida, applications for grants submitted by the planning consultant or governmental agency under any of these programs are reviewed for completeness regarding indicated financial and environmental health needs by the State Clearinghouse of the Department of Administration and the appropriate state agency responsible for solid waste.

CODES

The design and operation of sanitary landfills in Florida must comply with all regulations of the State of Florida which are currently in effect, or as may be revised or amended. Some counties and cities also have codes that may contain additional requirements above the State regulations, and in such instances it will be necessary to comply with applicable local codes in addition to the State regulations.

DUMP CLOSING AND CONVERSION

In some of the counties in Florida, the county has established "convenience" dumps located so that the residents will not have to travel very far to dispose of their solid wastes. The material in these dumps usually is covered at infrequent intervals, if at all.

While it might be possible to convert each of these dumps into a sanitary landfill operation that will conform to all existing regulations, it most probably would not be practical, in most instances, when economy and efficiency are taken into consideration.

To correct such a situation requires a study be made of the waste disposal problem with the objective being to develop a long range plan for the county, or counties, involved. The plan would consider all aspects of disposal of garbage, rubbish, and other solid wastes and suggest methods of financing the operation.

Before a dump can be properly closed an acceptable disposal method and site must be planned, designed and constructed. A more acceptable method should offer the following advantages to those living in the service area:

A. The increased protection of public health and safety.

B. An increased land value created by a sanitary landfill as opposed to the land value reduction created by a dump.

C. The greater revenue obtained by an increased tax income due to a closed dump vs. a new sanitary landfill.

D. Lower treatment costs of future water supply due to lower polluting potential of a true sanitary landfill.

The effective closure of a dump must be a planned operation and not a spontaneous guess-work procedure done without professional direction. The following dump closure procedure should be carefully followed to insure the elimination of all health and environmental hazards.

A. Provide an alternative disposal site or method.

B. Restrict unauthorized access (fence).

C. Display information signs.

D. Assign a qualified supervisor to the site.

E. Stop all burning at the site.

F. Stop all scavenging.

G. Stop the water pollution which can be immediately prevented or controlled.

H. Close the dump to new refuse or establish a spot on it for the new sanitary landfill.

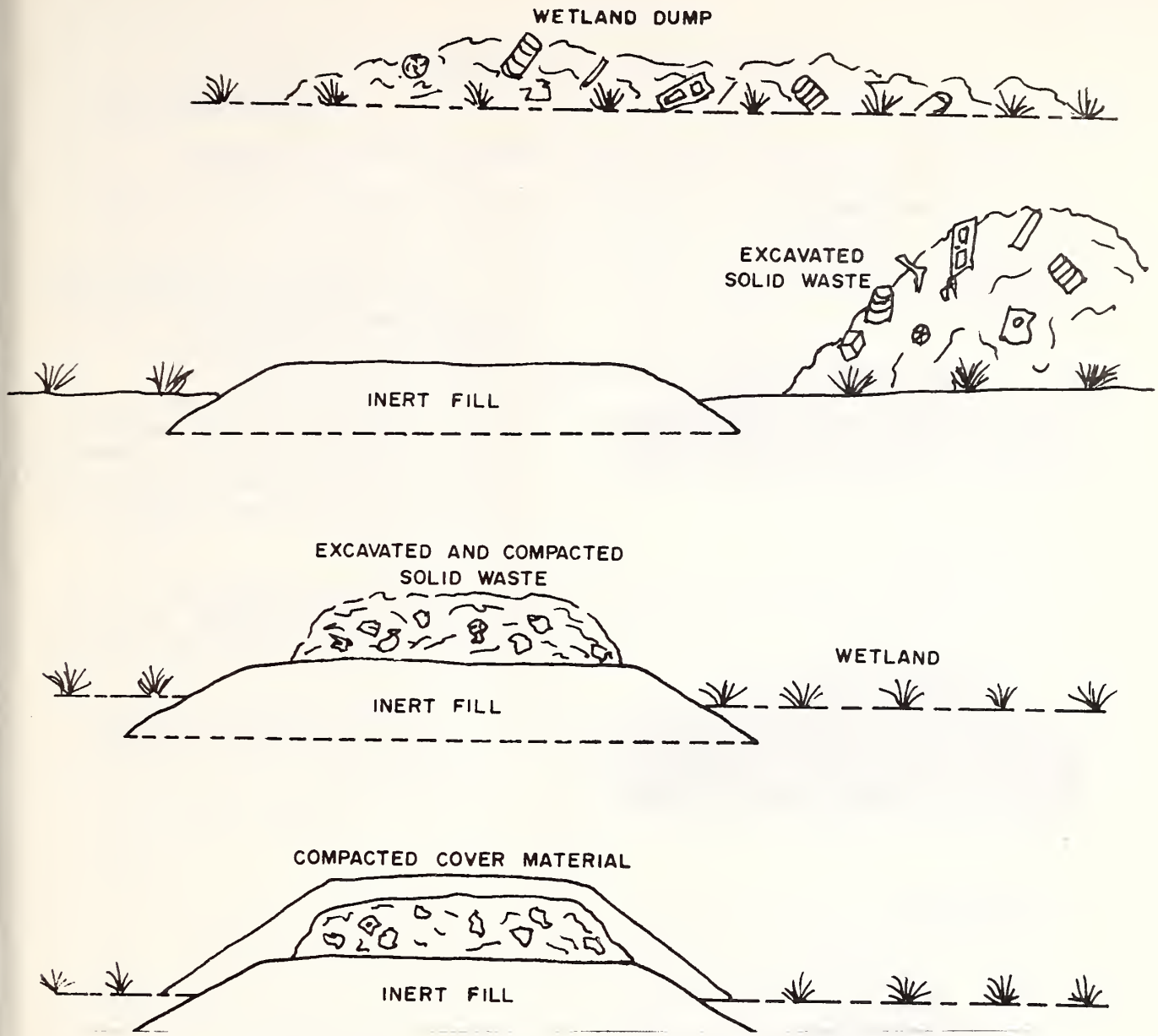
I. Exterminate insects and rodents.

J. Provide necessary surface drainage.

K. Clean up the solid wastes, compact and cover with two feet of earth.

L. Maintain the surface of the area and prevent litter.

FIGURE 2 - WETLAND DUMP CLOSURE



This figure is from Closing Open Dumps, by Brunner, Keller and Newton.

This method is used in a marsh or other area where the water table is continously or intermittenly exposed at the surface.

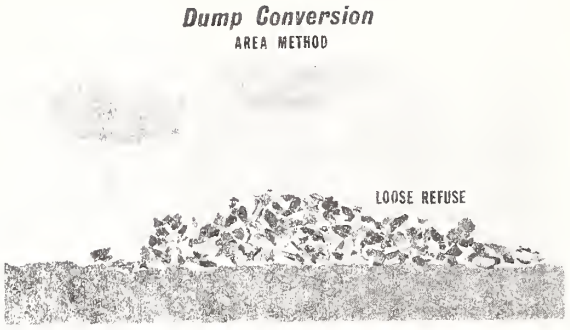
The solid waste is first removed and then separated from the water by placement of a mat of impervious material that reaches above high water level.*

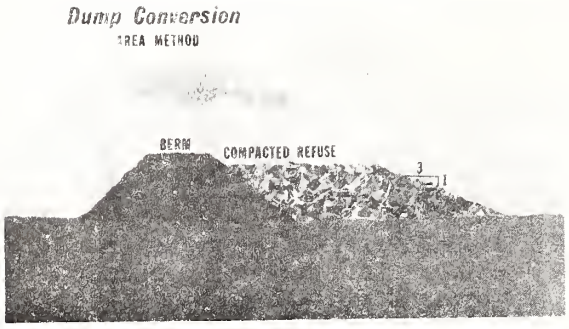
Solid waste may also be separated from the ground water by diverting the flow of water or by lowering the ground water level.

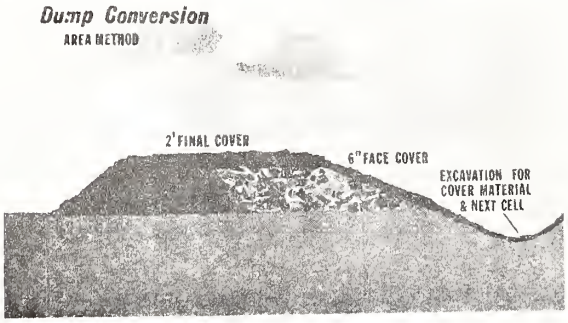
*Open Dump Closing - Alternate Procedures, Solid Waste Management Office, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1971.

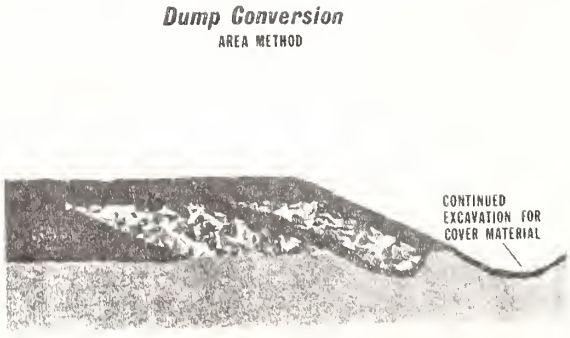
FIGURE 3

DUMP CONVERSION - AREA METHOD









The area method is used where high water tables may prohibit the excavation of trenches.

The loose refuse which generally is spread over a large area, is first stockpiled and then compacted against an earth berm using the cell concept for sanitary landfill construction.

Soil cover material may be hauled in from adjacent areas or secured at the toe of the working face as shown.

The site should be graded periodically to avoid ponding of surface runoff.

Source: Open Dump Closing - Alternate Procedures, Solid Waste Management Office, U.S. EPA, Cincinnati, Ohio, 1971, Dump Closing I, page 3.

PLANNING OUTLINE

Problems in planning should be approached from many directions and thoroughly evaluated before an acceptable plan of action can be developed. An outline such as the following should be used in developing a solid waste disposal plan.

A. Review all available comprehensive community planning reports including data and analyses, land use plans, plans for public facilities and established priorities for the regional, county or metropolitan areas.

B. Survey and analyze the solid wastes problem according to sources (residential, commercial, industrial, and agricultural) and methods of disposal to meet present and future needs. Such a study should include present data on population; refuse volume and characteristics; haul distances; highways; and traffic load as well as projections of this data.

C. Locate and investigate solid waste disposal sites such as abandoned stripmines, lowlands, etc. with special attention to land reclamation potential, topography and hydrogeology. The report should include:

1. Land Resource Survey - land area available, life of site, cost of land, distance to electrical and public water supply connections, zoning regulations, adjacent land uses, and access roads.

2. Transportation Survey - highways, load limits, bridge capacities, underpasses and railroads.

3. Environmental Survey - depth of ground water, types and depths of soils, types of underlying strata (limestone, shale, etc.), distance to private wells, location of surface waters (50 year flood levels), topography, rainfall frequency and intensity, temperatures, air pollution and noise effects.

4. Social and political factors involving aesthetics and public acceptance.

D. Explore processing methods such as incineration, grinding, compacting and recycling to be used with a sanitary landfill regarding costs, advantages, and disadvantages.

E. Consult local (city and county) health and pollution control departments, arthropod control programs, and the state agency having responsibility for solid waste to obtain both site and operational plan approval.

F. Develop a protective land development ordinance* to provide a comprehensive land management program including:

1. Open space areas - such as buffer zones.
2. Recreational areas including playgrounds, athletic fields, and parks.
3. Agricultural lands and nurseries.

G. Create a public relations program to arouse continuing public interest about the problem and its solution. The importance of acquiring suitable sites for solid waste disposal now and the advantages of inter-municipal, county or regional operations should be emphasized.

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*A model ordinance which won an award from the National Association of County Commissioners was developed and adopted by the Polk County Board of County Commissioners.

H. Compile a complete cost summary on:

1. Acquisition and preparation of a site.

2. Equipment and depreciation.

3. Operation and maintenance.

4. Total cost and method of financing.

    a. Present systems

    b. Alternative systems

    c. Recommendations for improvements; general plans (not detailed engineering plans), implementation schedule; construction and operating criteria.

    d. The agency responsible for implementation of the proposed project including staffing; county, regional, contractural or intermunicipal arrangements; and whether the public or private sector is to perform the collection and/or disposal.

DESIGN

COMPETENT DESIGNER

To properly design a sanitary landfill in Florida, a competent individual or firm familiar with the region should be selected. It is preferable to have the County Engineer or Mosquito Control Director involved since they are usually more familiar with sanitary landfilling techniques and the modifications necessary to make it compatible with the area.

USE OF PLAN

Adherence to a plan such as the one mentioned in the previous chapter will help make possible the creation of a sanitary landfill which will serve the public at the lowest cost. A sanitary landfill is created to provide an efficient means of solid waste disposal while at the same time protecting the public health and the environment.

SITE SELECTION

Before purchasing a site to be used as a sanitary landfill, two things are of prime importance: (1) sufficient land should be purchased to handle all of the refuse produced by the municipality, county or region for from five to twenty years, and (2) a hydrogeologic study be made including test wells and soil borings.

Technical assistance for making a hydrogeological survey may be obtained from the Florida Department of Natural Resources, Bureau of

Geology and the United States Geological Survey. The following hydrogeologic requirements for a particular piece of property were developed by Joseph W. Stewart and Robert V. Hanan in Hydrologic Factors Affecting the Utilization of Land For Sanitary Landfills in Northern Hillsborough County, Florida.

"In west-central Florida, the following hydrologic characteristics would be considered when evaluating a proposed sanitary landfill site:

1. Type of unconsolidated material. (Soil) Favorable: Clay, silty clay, clayey silt, and silt. Unfavorable: sand.

2. Thickness of unconsolidated materials. Favorable: at least 25 feet. Unfavorable: less than 15 feet.

3. Site topography. Favorable: adequate drainage and not subject to flooding. Unfavorable: low swampy areas; areas subject to flooding; sinkholes and areas near sinkholes; along stream channels hydraulically connected with Floridian aquifer.

4. Ground-water levels. Nonartesian aquifer: Favorable: greater than 15 feet below land surface. Unfavorable: less than 5 feet below land surface. Artesian aquifer: Favorable: potentiometric surface* at least 5 feet above water table. Unfavorable: potentiometric surface near or below the water table.

5. Character of limestone aquifer. Favorable: dense, unfractured. Unfavorable: fractured and cavernous."

*Potentiometric surface - depth at which the water table would normally be if not affected by extraneous conditions.

As many of the hydrogeological criteria as possible should be satisfied to provide the greatest possible protection to water supply sources.

Owing to Florida's rapidly growing population, the demand for land and its price are skyrocketing. It is unfortunate that land

possessing the most suitable characteristics for sanitary landfilling is also the most desirable for homebuilding. The increasing cost of such land makes it imperative that land for solid waste disposal be purchased in sufficient quantity to support sanitary landfill operations for as long as twenty years. Figures 4 and 5 are designed to give only approximation of the land volume required by a community, county or region per year using projected national generation averages. Those using the chart should follow the example given.

For example, a cell with six feet of refuse would have six inches of daily cover and two feet of final cover (25 percent cover) to give a depth of eight and one-half feet. A sanitary landfill cell with six inches of daily cover, one foot intermediate cover, and two feet of final cover (approx. 50 percent cover) would by the same reasoning be nine and one-half feet deep. Using the example in Figure 4, the land required for 10,000 people, generating 5.5 pounds per person per day with a compaction rate of 600 lbs/cubic yard and 25 percent cover would be 25.51 acre feet per year. Dividing the number of acre feet by the cell depth of 8.5 feet the answer of 3.00 acres per year. Thus, for twenty years over sixty acres should be purchased NOW!

HIGH WATER TABLE PROBLEMS

The major obstacle to creating a sanitary landfill in Florida is the high ground water table. If the solid waste is deposited in the ground water table the amount of liquid (leachate) generated is increased as the waste matter decomposes. Leachate not only contaminates the shallow ground-water, but may also contaminate the deep

FIGURE 4

ANNUAL LAND REQUIREMENT
(AREAS OF 5,000 - 25,000 POPULATION)

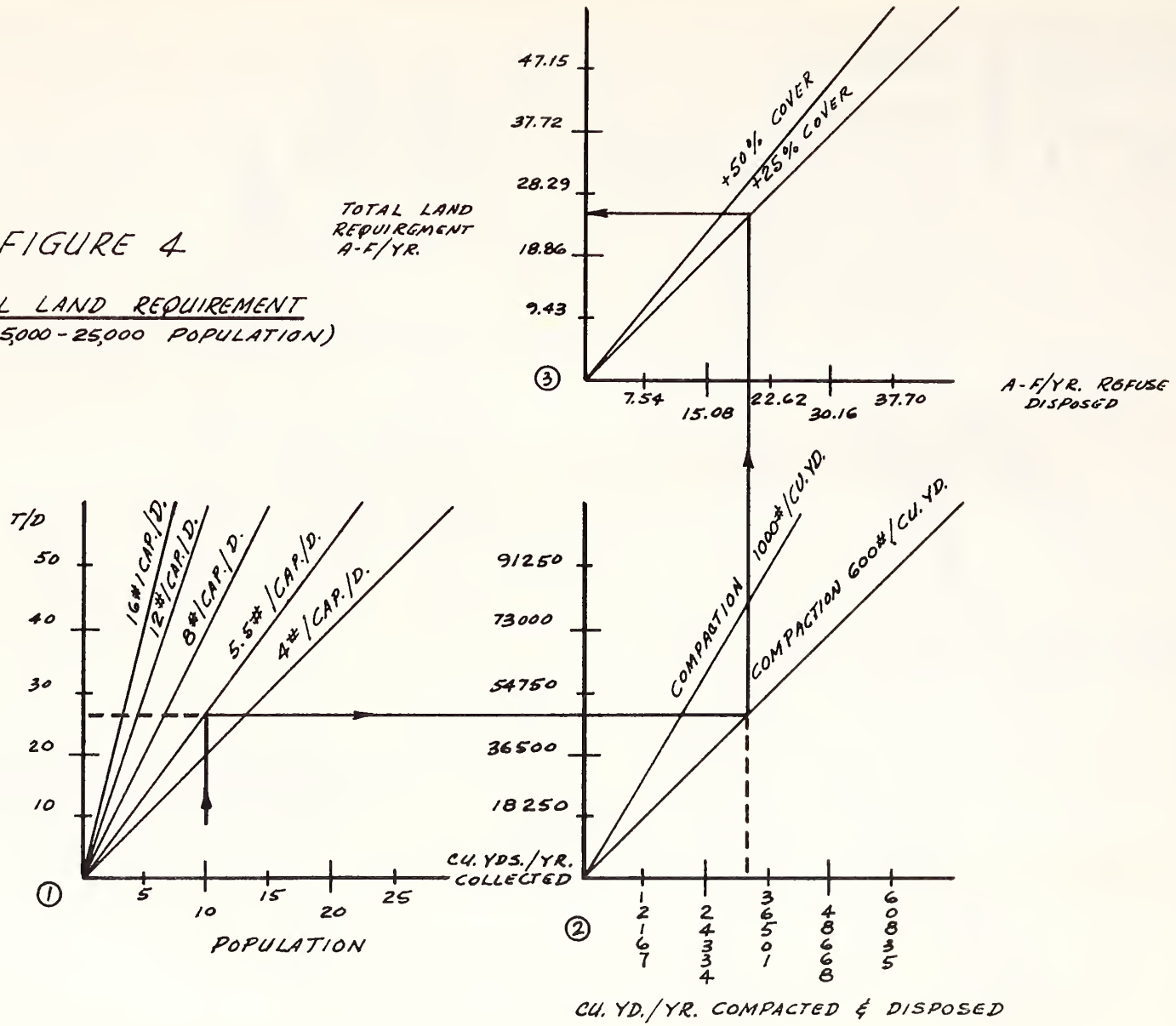
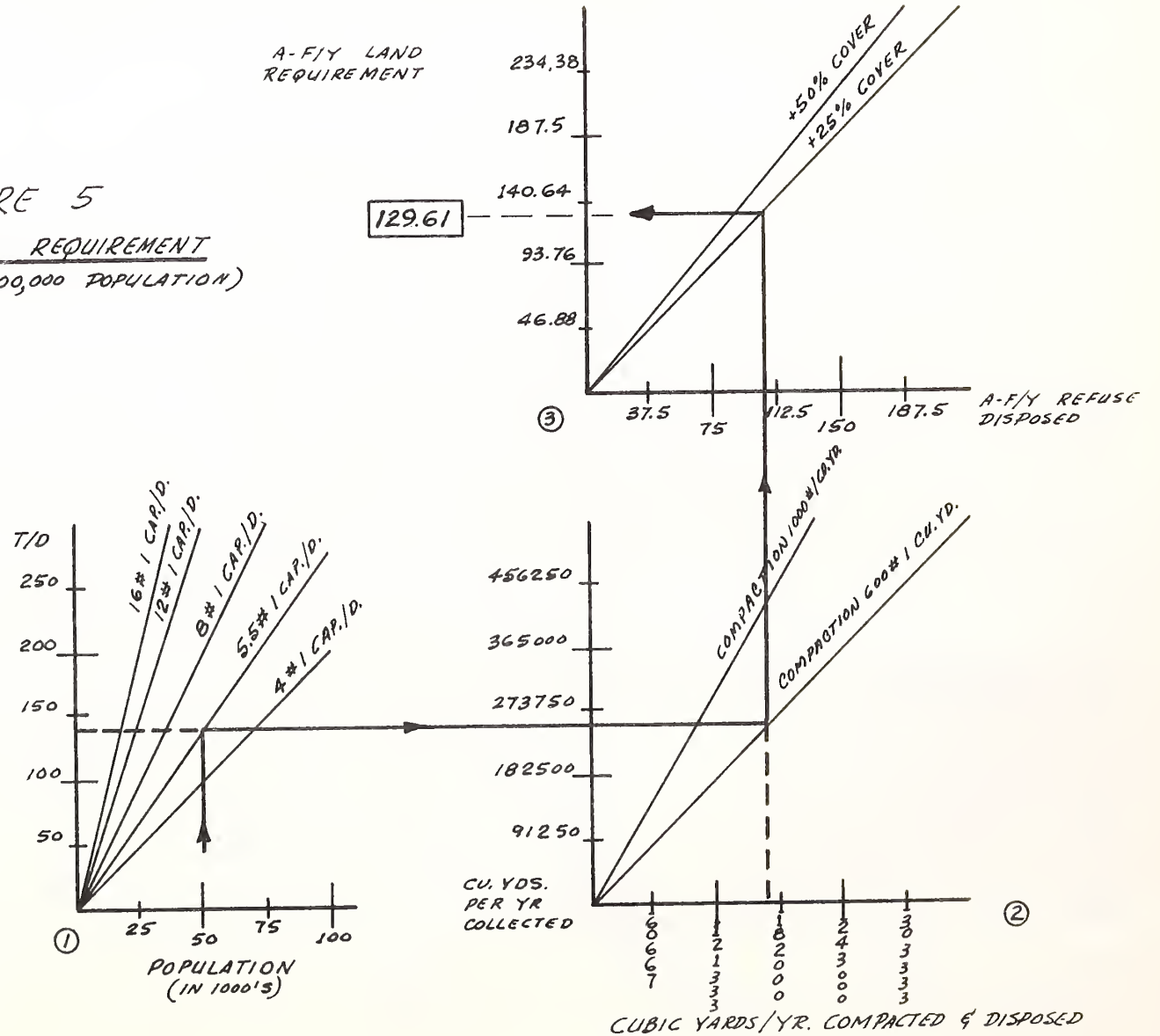


FIGURE 5

ANNUAL LAND REQUIREMENT

(AREAS OF 25,000 - 100,000 POPULATION)



public water supply sources if it moves through a solution cavity or other opening into the limestone above the Floridian or other aquifer. If the water supply is contaminated by leachate, then future treatment costs for drinking water will increase. In Figure 6, detailed analyses of sanitary landfill leachate compared with other types of wastes and the U.S. Public Health Service Drinking Water Standards are shown. "Studies conducted in California demonstrated that continuous water movement through an acre-foot (one acre of refuse one foot deep) would leach out approximately 1.5 tons of sodium plus potassium, 1.0 tons of calcium plus magnesium, 0.91 tons of chloride, 0.23 tons of sulfate, and 3.9 tons of bicarbonate in one year."[3] Biological contamination of ground water can rise to the point that treatment of the leachate by chlorination would be required. These facts (chemical and bacteriological contamination) coupled with a high water table accentuate the need for proper control of leachates.

HIGH WATER TABLE AND GAS

Gas production is the second area which becomes a problem when solid wastes are deposited in the ground water table since gas production increases with moisture content. Carbon dioxide, methane and nitrogen are the standard gases produced by solid waste decomposition. Carbon dioxide can cause a problem in that it is heavier than air and is readily soluble in water thus increasing the hardness (mineral content) of the water. Methane gas is explosive in concentrations of between five and fifteen percent in the presence of oxygen.

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[3] J. A. Salvato, W. G. Wilkie, & B. E. Mead, "Sanitary Landfill Leaching Prevention & Control," Journal Water Pollution Control Federation, (Washington, D.C.) Page 2092.

FIGURE 6

U. S. PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS AND COMPOSITION OF VARIOUS LIQUID WASTES
(in parts per million)

Substance	U. S. Public Health Service standards[a]		Leachate			Influent sewage[i]	Effluent sewage[i]	Slaughter-house wastes[j]	Chemical plant effluent[k]
	Group I[a,b,c]	Group II[d,e]	Blackwell[f]	LW5B Du Page[g]	LW6B Du Page[h]				
Alkyl benzene sulfonate	0.5			0.72	0.30				
Arsenic	0.01	0.05	4.31	< 0.10	4.6				
Chloride	250		1,697	1,330	135			320	1,070
Copper	1		0.05	< 0.05	< 0.05	0.450	0.032		2.1
Carbon chloroform extract	0.2								
Cyanide	0.01	0.2	0.024	< 0.005	0.02		0.051		
Fluoride		3.4		2	0.31				800
Iron	0.3		5,500	6.3	0.6	2.600	0.938		51
Manganese	0.05		1.66	0.06	0.06				0.48
Nitrate	45		1.70	0.70	1.60				864
Phenols	0.001								
Sulfate	250		680	2	2			370	8,120
Total dissolved solids	500		19,144	6,794	1,198			2,690	16,090
Zinc	5			0.13	< 0.10	0.638	0.366		
Barium		1	8.5	0.80	0.30				
Cadmium		0.01	< 0.05	< 0.05	< 0.05	0	0		
Chromium (Cr^{+6})		0.05	0.20	0.15	< 0.05	0	0		
Lead		0.05		0.50	0.50	0.138	0.138		
Selenium		0.01	2.7	< 0.10	< 0.10				
Silver		0.05	< 0.1	< 0.1	< 0.1				
Ammonium						19	16		198
Alkalinity (as $CaCO_3$)			3,255	4,159	1,011			440	760
Hardness (as $CaCO_3$)			7,830	2,200	540				0
Phosphate			6	1.20	8.90			66	74
Titanium									0.97
Aluminum			2.20	0.10	0.90				6.4
Sodium			900	810	74				6,190
Hexane solubles			350	18	7	22.4	11		
Biological oxygen demand[l]			54,610	14,080	225	104	17	3,700	
Chemical oxygen demand			39,680	8,000	40	240	70	8,620	
pH				6.3	7.0	7.2	7.4	8.1	6.2

[a] U. S. Department of Health, Education and Welfare (1962).
[b] Nitrates exceeding 45 ppm dangerous for infants.
[c] Should not be used if more suitable supplies available.
[d] Larger concentrations should be rejected.
[e] Fluoride is temperature dependent.
[f] Probably represents leachate from compaction and infiltration.
[g] Leachate from refuse about 6 years old.
[h] Leachate from refuse about 17 years old.
[i] Data provided by Metropolitan Sanitary District of Greater Chicago.
[j] Data from files of the Illinois Department of Public Health
[k] Rare earth and thorium production (Butler, 1965, p. 63).
[l] Twenty-day biological oxygen demand for leachate. Other values are 5-day BOD.

In a sanitary landfill, there is rarely any oxygen present when methane reaches these concentrations; however, if the surface of the landfill is covered with an impermeable soil such as clay or paving with no provision for venting, this gas can travel long distances underground and enter buildings. In theory, if the decomposition of refuse is allowed to be carried to completion, 13,200 cubic feet of gas can be produced for every ton of refuse containing 25 percent inerts.[4]

One study of an actual sanitary landfill conducted over an extended period, produced approximately 125 cubic feet of gas per ton of refuse. The composition of the gas during the early stages of decomposition was 88 percent carbon dioxide, five percent methane and 5.2 percent nitrogen; the composition of the gas shifted in the latter stages to 51 percent carbon dioxide, 48 percent methane, and 0.4 percent nitrogen. The results of this study showing the changes in the percentages of carbon dioxide, methane and nitrogen over the time period can be seen in Figure 7.[5]

SOILS

Soils play an important part in leachate quantities, movement and control. The soils in many parts of Florida are unsuitable for sanitary landfilling due to the highly permeable qualities of the sands. These soils permit water to penetrate easily into the refuse thus increasing leachate and gas production. The most suitable soils

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4 Dirk R. Brunner and Daniel J. Keller, Sanitary Landfill Design and Operation, (U.S. EPA, Cincinnati, Ohio, 1971), page 15.

5 Ibid.

FIGURE 7

LANDFILL GAS COMPOSITION

Time Interval Since Start Of Cell Completion (Months)	Average Percent By Volume N_2	CO_2	CH_4
0 - 3	5.2	88	5
3 - 6	3.8	76	21
6 - 12	0.4	65	29
12 - 18	1.1	52	40
18 - 24	0.4	53	47
24 - 30	0.2	52	48
30 - 36	1.3	46	51
36 - 42	0.9	50	47
42 - 48	0.4	51	48

SOURCE: Sanitary Landfill Design and Operation, by Dirk R. Brunner and Daniel J. Keller.

for this type of work are sandy loams or soils containing a certain amount of clay but less than 40 percent. See Figure 8.

CONTROL

It is fortunate that the control of leachate and gas generation due to ground water can often be done by the same means. There are several techniques available to do this, however, the rate of leachate and gas generation caused by the high annual rainfall can be reduced by adequate compaction and grading of cover material. Other control mechanisms are shown in Figure 9. In Florida, the warm climate which generally favors the state year around causes a more rapid rate of refuse decomposition thus increasing the production of gas and leachate.

In areas of high ground water, it should be noted that the best method of protecting the ground and surface waters of the state is through the use of a liner in conjunction with the high rise sanitary landfill variation of the general method of sanitary landfill. Liners may be made of hypalon (a rubberized plastic sheeting), asphalt-fiberglass sheeting, an asphalt membrane, bentonite-montmorillonite (a special clay and its moisture holding additive) or clay. However, the use of liners in Florida have a number of possible disadvantages:

1. Floating out of the ground, much like an empty swimming pool during 50 year flood conditions.
2. Possibility of inadequate seals between sheets during construction.
3. Unknown or undetected fractures or cracks which may develop during use.
4. Very high costs of land development and installation.

FIGURE 8

COVER MATERIAL SUITABILITY OF GENERAL SOIL TYPES

Function	General soil type					
	Clean gravel	Clayey-silty gravel	Clean sand	Clayey-silty sand	Silt	Clay
Prevent rodents from burrowing or tunneling	G	F-G	G	P	P	P
Keep flies from emerging	P	F	P	G	G	E*
Minimize moisture entering fill	P	F-G	P	G-E	G-E	E*
Minimize landfill gas venting through cover	P	F-G	P	G-E	G-E	E*
Provide pleasing appearance and control blowing paper	E	E	E	E	E	E
Support vegetation	P	G	P-F	E	G-E	F-G
Be permeable for venting decomposition gas†	E	P	G	P	P	P

E, excellent; G, good; F, fair; P, poor.
*Except when cracks extend through the entire cover.
†Only if well drained.

This is from Sanitary Landfill Design and Operation by Dirk R. Brunner and Daniel J. Keller.

FIGURE 9

FACTORS IN LEACHATE PRODUCTION

FACTOR	QUANTITY	MEANS OF CONTROL
Water from decomposition	Negligible in most cases may be significant with highly putrescible organic wastes.	1. Avoid burying large quantities of highly putrescible wastes without thorough mixing with other refuse.
Groundwater	Negligible to very large depending on soil permeability and location of fill in relation to groundwater table, hydraulic gradient, & Soil layering.	1. Design area to minimize tributary watershed. 2. Install ditching to intercept groundwater moving into fill. 3. Maintain groundwater level below fill. 4. Install an impermeable membrane or dam to separate refuse from surrounding groundwater.
Surface water drainage	Negligible to very great depending on precipitation, watershed area, & runoff characteristics.	1. Design area to minimize tributary watershed. 2. Divert surface water around area. 3. Pipe water through fill area in tight pipes. 4. Use lining for surface ditches.
Infiltration and percolation to refuse from precipitation falling on area		1. Maintain surface to prevent pooling. 2. Slope surface to allow runoff (2%) 3. Use relatively impermeable material for cover with topsoil to control soil moisture. 4. Plant high transpiration shallow rooted cover crops.

SOURE: "Sanitary Landfill - Leaching Prevention and Control", Salvato, Wilkie & Mead, Journal Water Pollution Control, OCT., 1971.

This is not to say don't use a liner, but simply consider all aspects of the problem before making any decision.

GENERAL METHOD

The general method of sanitary landfilling in the high water table areas of the state begin with the purchase of a hydrologically surveyed site, (a survey of underlying soil and water conditions). The areas shown in the accompanying figures are not drawn to scale but are simply for illustrative purposes. At least five acres of the site should be set aside for polishing ponds, spray irrigation systems, access roads, scale, employee and maintenance facilities with the remaining land to be used for solid waste disposal. The area intended to be used for the disposal of solid wastes should be divided into segments (each large enough to sustain operations in three to four month increments) as shown in Figure 10(a). Only the segment (tract) to be used immediately should be grubbed and cleared to better control surface water run-off resulting from rain storms. The first tract should be surrounded by a perimeter ditch sloped to a central sump with a grade of three to five percent. The excavated earth (spoil) should be placed on the outside of the trench along the three adjacent sides most likely to receive surface run-off from surrounding areas as shown in figure 10(b), and the spoil created by the excavation of the fourth side may be used to construct an earthen berm against which cell construction may be begun, when the site begins to receive solid wastes.

The purpose of the perimeter ditch is to intercept ground water which would ordinarily flow through the site; to artificially lower the water table within the tract; to collect leachate flowing from the refuse cells once they become saturated; to provide some oxidation and dilution of the leachate; and to collect storm run-off from the disposal areas.

A holding pond should be constructed near the ditch sump point as shown in Figure 10(b). The pond should be large enough to contain all the above liquids collected during the rainy season. The excavated earth (spoil material) from the construction of this pond should be stockpiled for use as additional cover material. A pump should be located between the ditch sump and this pond to transfer the liquid from the ditch to the pond. Should the bacteriological samples from the ditch or surrounding test wells become too high, it is recommended that a chlorinator between the pump and the pond be installed. It should be noted that a pond is used to allow solids to settle out and to allow further oxidation of the liquid waste. Discharge from this pond may be made either through a ditch or by pumping the waste water through a sprinkler system (spray irrigation).

Spray irrigation provides treatment of the waste liquid by exposing the individual droplets to light and air, then by filtration through the earth. This method of leachate treatment is currently being used in Manatee County, Florida, and also for the disposal of sewage treatment plant effluent in various parts of the State.

The disposal at the site is done by the area method which consists of initially compacting solid wastes against the earth berm and excavating

the cover material from the toe of the cell as shown in Figure 13. This method proceeds as shown in Figure 10(b) until the end of tract one is reached, then the end perimeter ditch is filled with earth. It is then possible for the interior access road to be filled with refuse and cover material toward its entrance, to make maximum use of the land. The method of filling the entire site proceeds by the basic plans shown in Figure 10(b), Figure 11, and Figure 12. Upon completion of the operation, the site should be graded for drainage, and the perimeter ditches and holding pond filled.

FLORIDA HIGH RISE METHOD

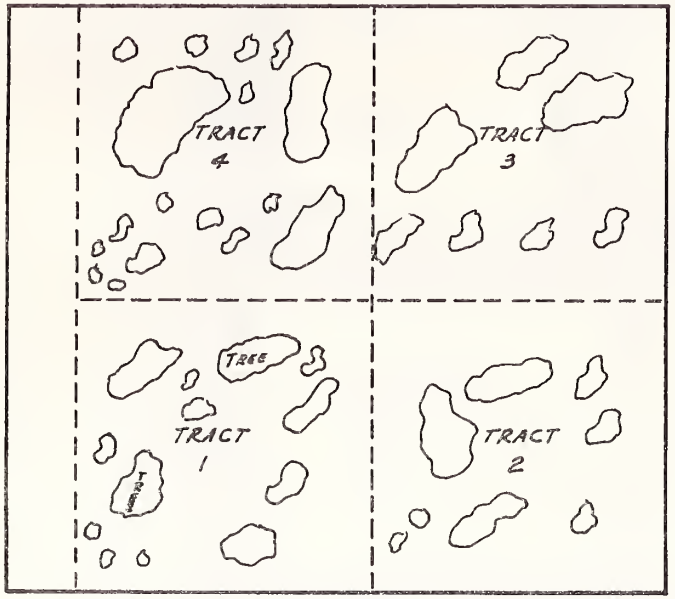
In areas of high population and refuse generation, it is no longer economically feasible to purchase large sanitary landfill sites. One answer to conserving space is the construction of sanitary landfills above grade to form huge refuse mountains or plateaus twenty to thirty feet above the surrounding terrain. This is not an untried method since one is being constructed at Virginia Beach, Virginia extending sixty-seventy feet above grade. The end use of this site is to be a 10,000 seat amphitheater overlooking a manmade lake (from which cover material was obtained) and a soap box derby ramp. Another mountain of refuse has been partially completed in DuPage County, Illinois and is planned for use as a winter ski slope and summer park.

The land requirements for a net forty-acre landfill to be constructed above grade, would be in excess of sixty acres to allow for excavation of cover material. It is realized that in most areas where this method can be used the water table is exceptionally high and cover

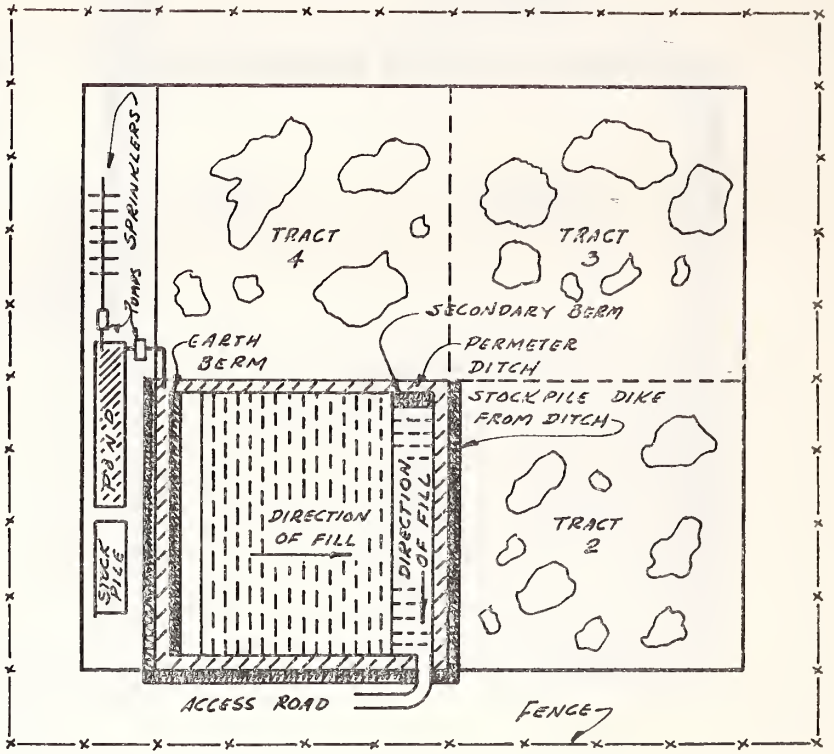
FIGURE 10

LAYOUT AND DEVELOPMENT OF THE GENERAL METHOD

(AREA CONCEPT)



(a)



(b)

FIGURE 11

LAYOUT AND DEVELOPMENT OF THE GENERAL METHOD

(AREA CONCEPT)

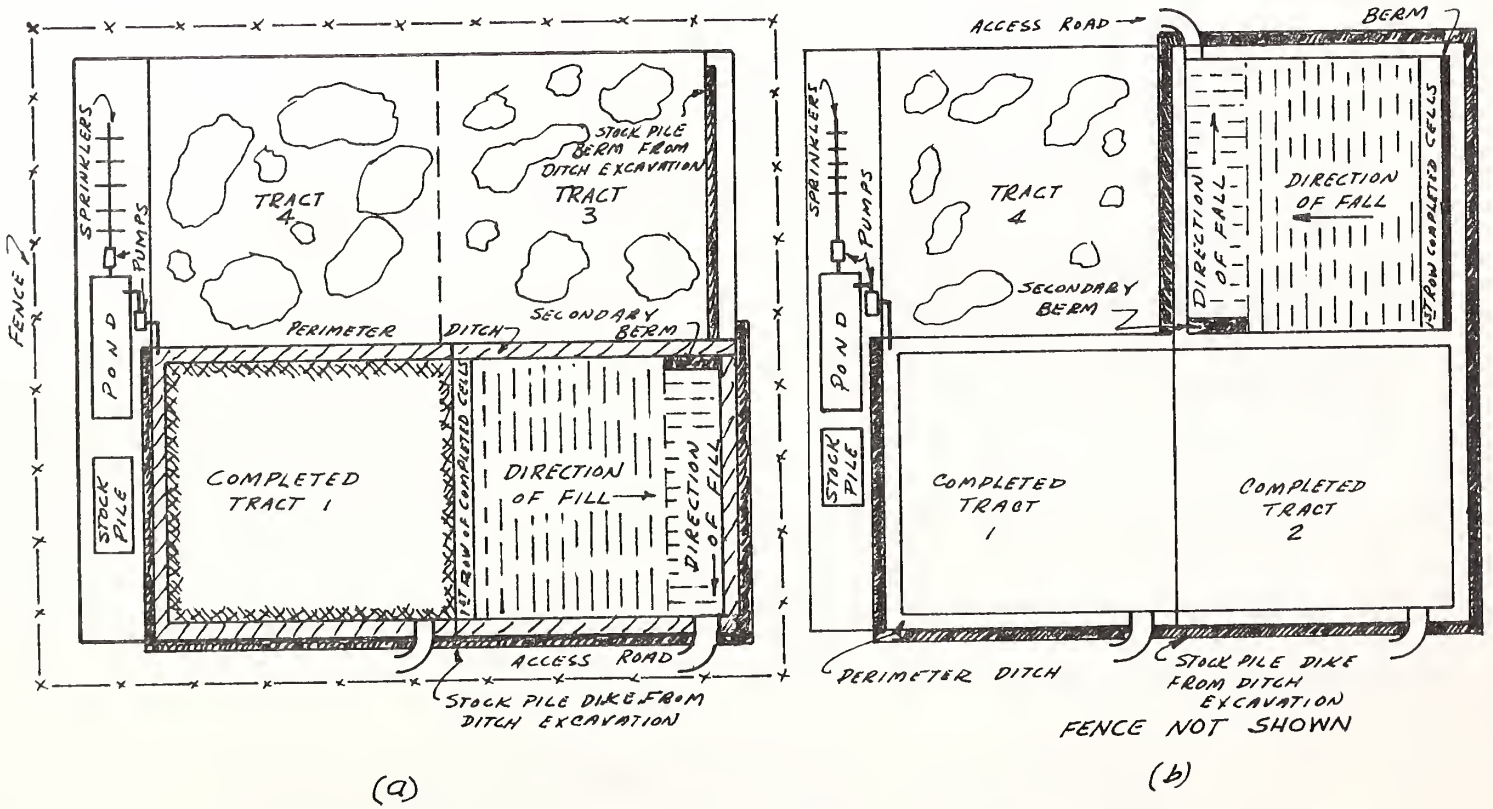
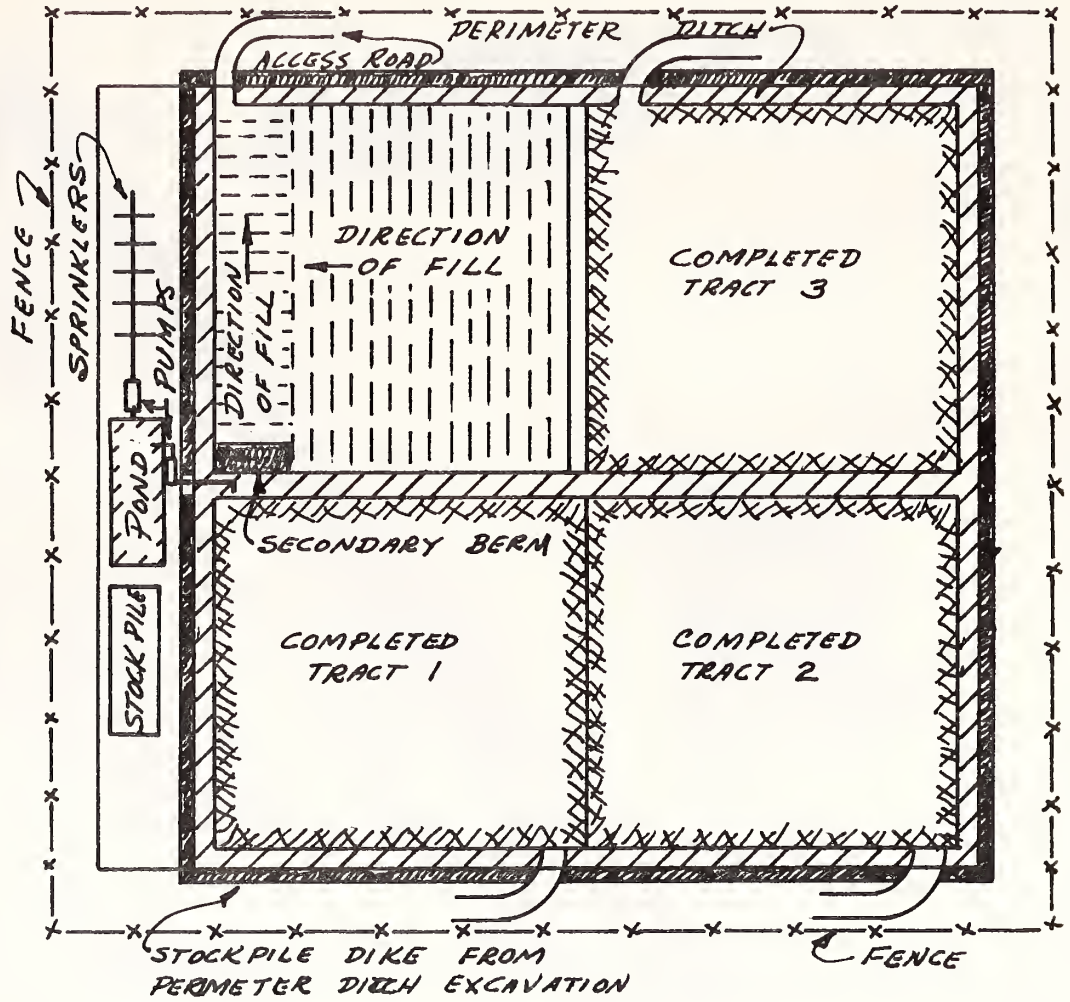


FIGURE 12

LAYOUT AND DEVELOPMENT OF THE GENERAL METHOD

(AREA CONCEPT)



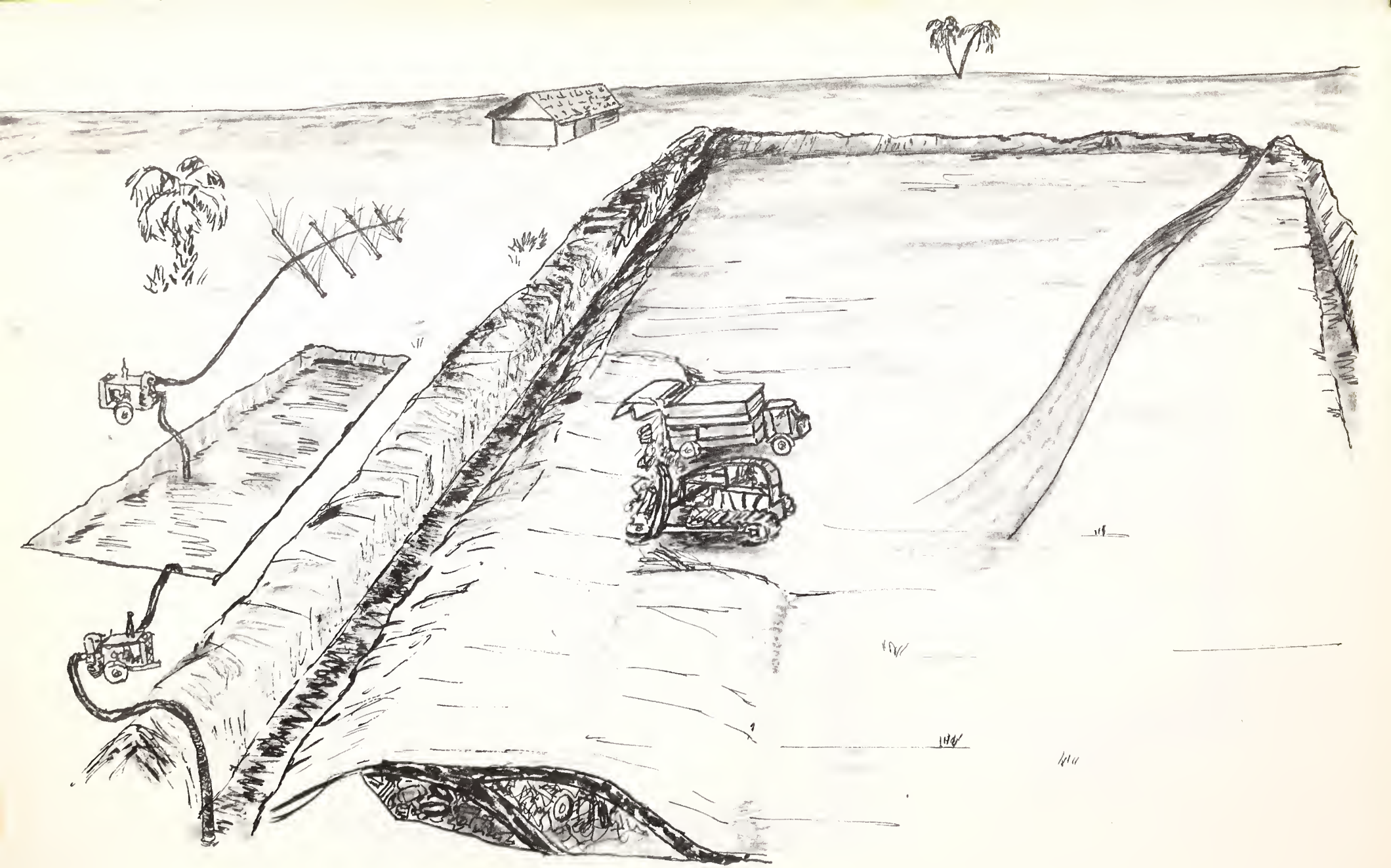


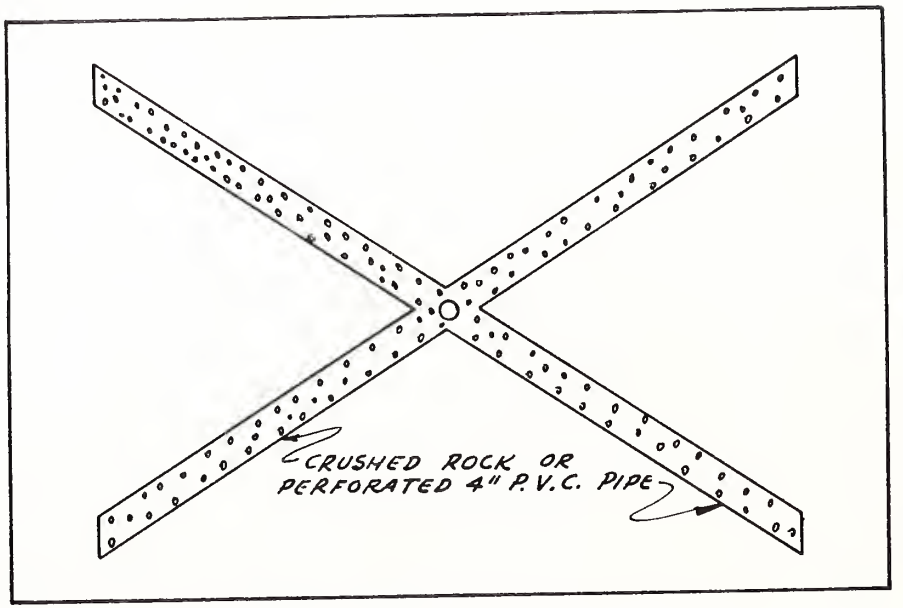
FIGURE 13

material is scarce. About twenty acres of the site should be set aside for the excavation of cover material until the water table is reached. After the water table is reached, pumps must be brought in to keep the pit dewatered so that trucks, draglines or self-loading panscrapers can get down into the pit to excavate cover material. The side slopes of the excavated pit should be no less than one and one-half to one (a one and one-half foot drop for every one foot horizontal) to control growth of aquatic plants.

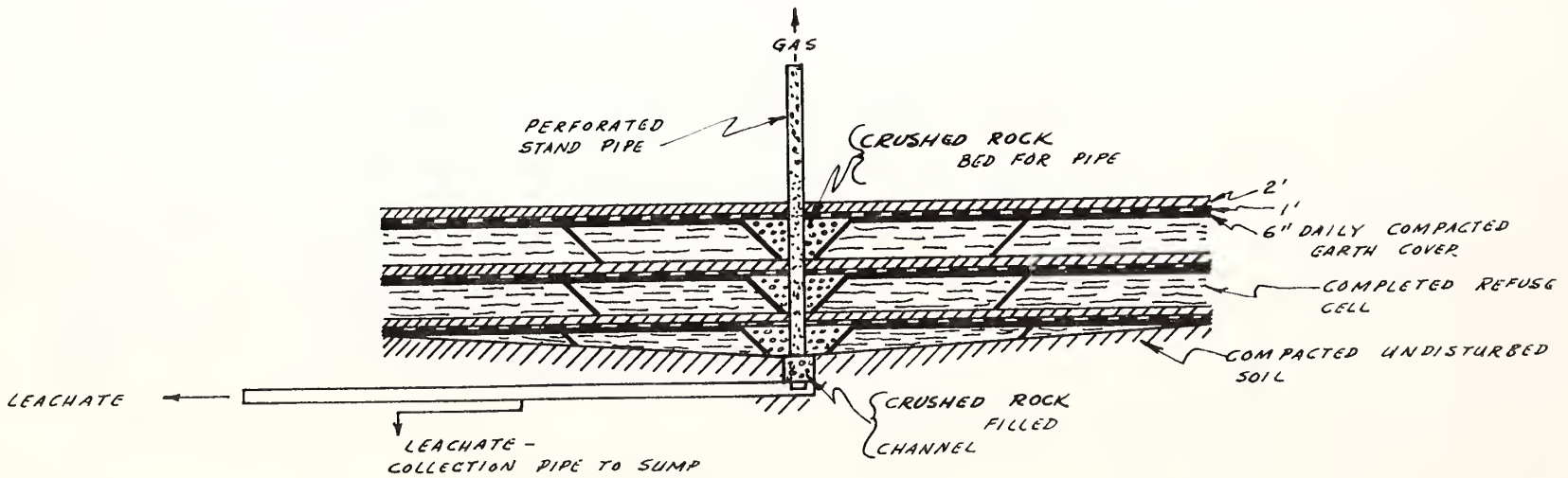
The basic method of site preparation and the order of sanitary landfilling are almost the same as the General Method; however, the preparation of each tract differs as shown in Figure 14. The soil should be well compacted to promote leachate run-off into the crushed rock filled channel so that it may be pumped out through the buried drain pipe into the holding pond. It may prove necessary to treat the effluent from the holding pond with chlorine before discharging it into the holding pond or receiving stream.

Leachate control for each set of lifts (one cell depth) is obtained by placing a vertical perforated pipe directly into the sump point for the drain pipe. This pipe should be put up in sections as each lift is completed and mounted in crushed rock where possible. Four-inch perforated PVC pipe or channels filled with crushed rock about one foot deep and two feet wide extending from the pipe diagonally to within three fourths the distance to the corners of a segment should be placed on each completed set of lifts after two feet of cover has been applied. The channels or pipe provide a path for leachate to the sump and the gas

FIGURE 14



FLORIDA HIGH RISE METHOD
BASE PREPARATION AND
POLLUTION CONTROL SYSTEM



to the atmosphere. This system may be seen in Figure 14.

This method requires about fifty percent cover material in the form of six inches of compacted daily earth cover, one foot of intermediate compacted earth cover after the set of cells are one week old, and a two foot final earth cover compacted in six inch layers prior to the second layer of cells. The extra cover material would reduce uneven settlement due to the fact that more material is available to fill voids created by decomposing refuse. According to the American Public Works Association (APWA) as much as 75 percent of the cover material seeps down to fill voids created by decomposing refuse. The reduced settlement will decrease the amount of maintenance necessary to control drainage, and cover cracks caused by uneven settlement.

The ditch passing through the center of the site as in the General Method should be filled with earth after all of the site has been filled with one set of lifts. Figure 15 shows a view of the site as the highest lift is completed on it, and the other tracts which already have several sets of lifts on them are being readied for the next lift. Additional lifts are added in the same sequence as originally described to permit even settlement. It is recommended that side slope grades (comprised of completed cells) not exceed 25 percent (1 foot in 4 feet) to minimize erosion.

This is an excellent method for large cities and counties having highly concentrated areas of population and few well located sanitary landfill sites.

FIGURE 15

ARTIST'S CONCEPTION OF FLORIDA HIGH RISE METHOD

The scarcity of adequate sites, coupled with equipment and manpower needs further accentuates the advantages of regional solid waste disposal systems.

WETLAND METHOD

The wetland method of sanitary landfilling is basically ideal for reclaiming marginal land where cover material is obtainable from a nearby source and a supply of construction debris, demolition rubble or trash is available. It is a relatively inexpensive method which offers a degree of protection to the quality of natural waters. See Figure 16.

The same basic procedure as described in the General Method is followed. The first tract to be used should be surrounded by a perimeter ditch to lower the water table in the immediate area; to collect any leachate from saturated refuse cells; to collect storm run-off from the site; and to dilute the leachate. From this point, sanitary landfilling proceeds by first filling above the zone of saturation (water level) with compacted construction debris, and demolition rubble. After the zone of saturation has been filled with this compacted material, it should have an additional cover of one to two feet of soil to fill the voids in the rubble and reduce the amount of leachate entering the ground water table. See Figure 3 for a typical cross section of such a cell. Then sanitary landfilling of municipal refuse may be done on top of this material as shown in Figure 16.

Cover material will have to be brought in from borrow areas; may be obtained as spoil from construction projects; or the system outlined

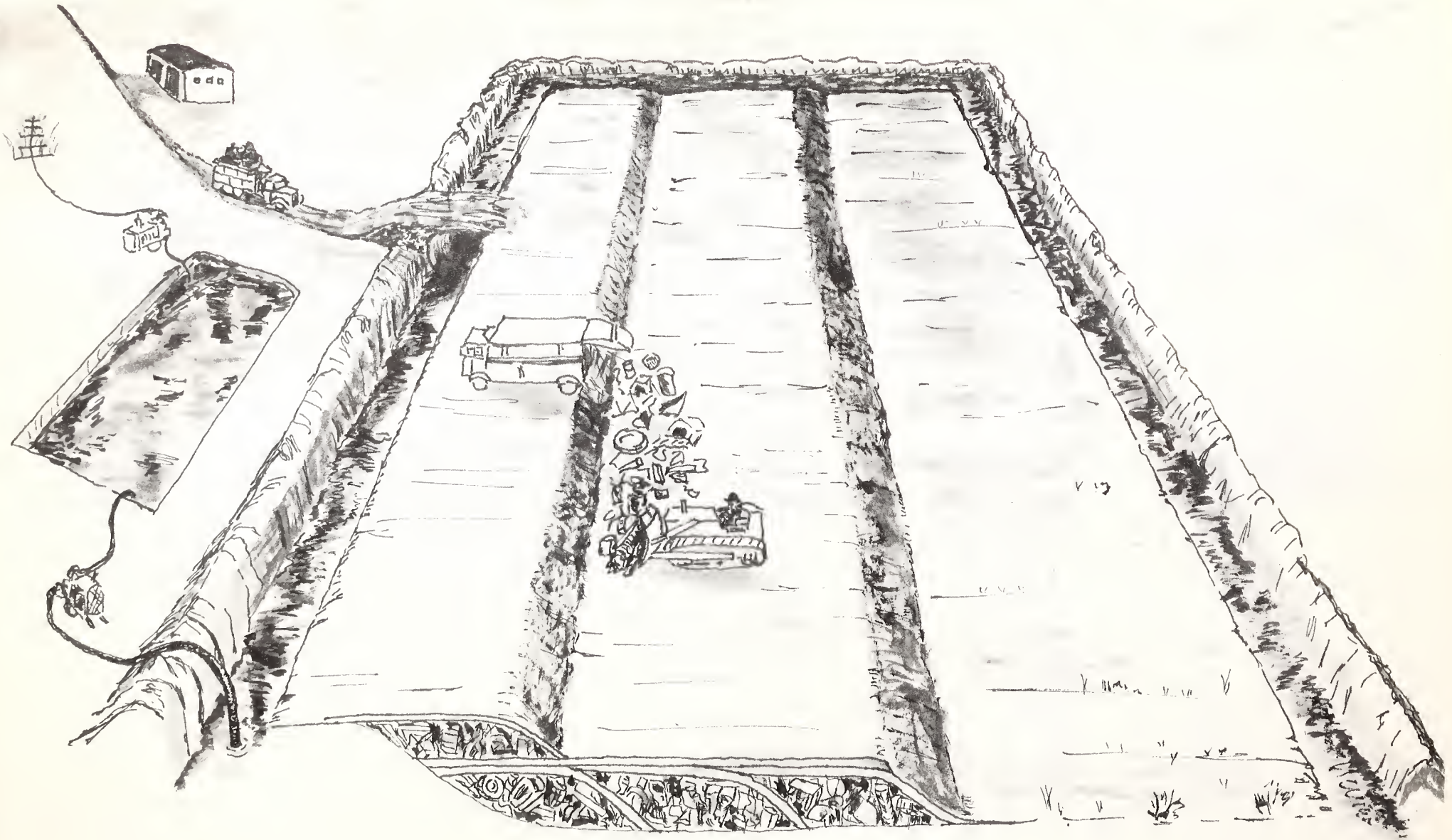


FIGURE 16

ARTIST'S CONCEPTION OF WETLAND METHOD

in the high rise method may be used. This way of landfilling is based on the area method (no trenches) which is the most acceptable method for all high water table areas.

The wetland method may be used as a base for the high-rise method if the channels through the center of the site are constructed and the necessary gas control methods previously described are used.

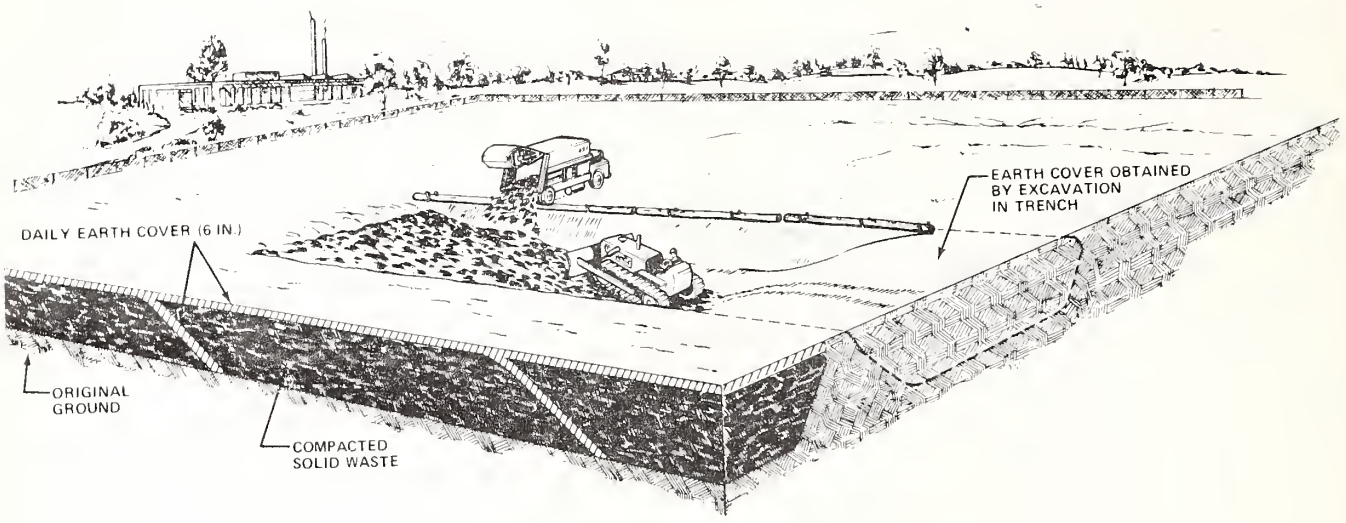
TRENCH METHOD

The trench method of sanitary landfilling is most suitable in areas where the shallow ground-water aquifer is located about 25 feet below the surface. In areas where this acquifer is less than 15 feet below the surface, this method even with pumping can result in contact between the refuse and the water, since the water table will again rise when pumping ceases. Such contact can result in prolonged contamination of shallow ground water.

This method is the same as the general method as far as digging perimeter ditches; a holding pond; and the use of a section approach; but this is where the similarity ends. Trenches are excavated ten-fifteen feet deep and one hundred-four hundred feet long, to provide a pit in which refuse cells can be constructed and cover material obtained. The refuse is compacted against one end of the trench at an incline until a cell six feet high and of practical dimensions has been constructed. This cell is then covered with six inches of earth cover at the end of the day or at such more frequent intervals as may be deemed necessary. Upon completion of the trench, it should receive a minimum final earth cover of two feet and if more than one lift is placed in a trench, each lift should receive one foot of intermediate cover. See Figure 17.

FIGURE 17

TRENCH METHOD



The trench method can be used most effectively where a high water table is not a problem.

After the perimeter ditches and holding ponds have been constructed, trenches are either partially or completely excavated. If the trenches are partially excavated, the bulldozer may place and compact solid waste while excavating cover at the opposite end of the trench.

Loose refuse dumped by collection vehicles is spread and compacted in accordance with the cellular concept of sanitary landfill construction. Upon completion of a cell the refuse is covered with six inches of compacted earth.

The illustration of this method was made by the Solid Waste Management office, U.S. EPA.

DESIGN OUTLINE

The following outline should be closely adhered to in designing a sanitary landfill. The information in the planning outline should be considered part of the design and as such be used with this outline:

I. Maps - A location map drawn to a scale of one inch equals one half mile showing the contours and elevation of the area surrounding the site; and a topographic map of the site drawn to a scale not to exceed one inch equals two hundred feet showing existing and final grades for the actual size.

II. Drawings which should show:

A. Property lines

B. Land use and a sanitary survey including existing habitations; other structures; public roads and highways; shallow and deep wells; trees; and land use within one mile of the site

C. Area and depth of the proposed fill

D. All borrow areas

E. Location and elevation of surface and highest ground waters

F. A wind rose to show prevailing winds

G. Special provisions for drainage and erosion control

H. Leachate treatment and control provisions

I. Necessary provisions for gas control

J. Method of operation and completion

K. Cross sections showing typical lifts not to exceed six feet compacted depth of refuse

L. The necessary grade for proper drainage of each lift and the final grade of the completed operation

M. Locations of stockpiled cover material

N. Access routes, approach roads and on-site roads

O. Fencing, direction and information signs

P. Weighing facilities, locker room; toilet and shower facilities; equipment shelter, and wash-out facilities

Q. Locations of existing and proposed utilities

R. Fire control and potable water supply locations

III. Geological Survey - data on geological characteristics of a proposed site from on-site testing.

A. Hydrogeological* investigations should obtain the following types of information.

1. Thickness and character of the overburden (soil)

2. Character of bedrock

3. Depth of the water table and potentiometric surfaces

4. Depth to the water table aquifer and artesian aquifer

5. Local and regional ground water flow systems

6. Chemical quality of surface and ground water

7. Frequency and extent of flooding of the area

8. Nature and volume of the waste materials to be buried[6]

*Technical assistance for making hydrogeologic surveys is available through the U.S. Geological Survey and the Florida Bureau of Geology.

IV. Soil Classifications and Characteristics - This data should include soil surveys published by the Soil Conservation Service of the U.S. Department of Agriculture, the Agricultural Experiment Station -

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6 Joseph W. Stewart & Robert V. Hanan, Hydrologic Factors Affecting the Utilization of Land for Sanitary Landfills in Northern Hillsborough County, Florida, (U.S. Geological Survey, Dept. of Natural Resources, Hillsborough Co. & City of Tampa, 1970).

University of Florida, The Florida Department of Natural Resources, realty subdivision data and data obtained from special test holes or borings over the area under consideration.

V. Equipment - Present and proposed types, number and sizes. A few factors to consider in equipment selection are:

A. Location, conditions, type and size of operation

B. Projected amounts of waste handled

C. Versatility and maintenance cost of the site

VI. Description of the proposed operating procedures explaining methods of:

A. Controlling the length and width of the working face

B. Disposing of large items, special industrial, and hazardous wastes

C. Confining papers to the site

D. Waste handling in the wake of a natural disaster

E. Emergency provisions for insect and rodent control

F. Providing adequate site supervision

G. Controlling fires

H. Maintaining an all weather access road

I. Posting operating hours, fee schedule, waste restrictions as well as the name, address and phone number of the operating agent

J. Placing signs to direct traffic

OPERATION

A sanitary landfill does not simply exist because it was planned and designed to be one, it must be operated as one.

A careful study of the definitions in Chapter 1 and the Florida Administrative Code results in 11 basic requirements for a sanitary landfill operation and some suggested considerations. These items are not only aimed at better protection of the public health but toward making the operation more acceptable to the public.

AESTHETIC CONSIDERATIONS

The entire site should be fenced on all sides to protect the neighborhood from blowing litter and to prevent unauthorized individuals from entering the site. If the area surrounding the site is strewn with blowing litter, the operation of the site in the public eye becomes a dump. Unauthorized persons at a sanitary landfill not only interfere with the efficient operation, but pose an imminent safety threat to both themselves and site personnel.

A thick growth of shrubs and trees indigenous to the area should be planted on all sides of the site, to screen the operation and make the sanitary landfill more acceptable. Shrubs and trees also help control blowing paper by catching loose litter, and provide a wind break. Thick vegetation planted around the site has the ability to cut down the noise level which might otherwise infiltrate the neighborhood and bring complaints from residents in the area.

The entrance to a sanitary landfill site should be an all weather road with a moderately sharp curve just inside the entrance so that all

refuse collection vehicles are out of sight behind a row of shrubbery as rapidly as possible to enhance the acceptability of the site. The entrance should have an attractive permanent sign giving the name of the site, its hours of operation, a schedule of charges, its present use (a sanitary landfill) and its planned use upon completion (a playground, park, etc.). This tells the public that this is a well planned project; that it will become something that they can use; and that it is worthy of their financial support.

REQUIREMENTS

The eleven basic items that must be considered in any properly designed and operated sanitary landfill are:

1. No Burning

Open burning of solid wastes creates obnoxious odors, air pollution, fire hazards, and public health hazards. Open burning immediately converts any sanitary landfill into a dump. It destroys public acceptance of the operation or any other proposed operation whether it should be a sanitary landfill or a dump.

The Florida Department of Pollution Control has a code which became effective July 1, 1971 prohibiting open burning except in specifically stated cases. Under this code, open burning connected with municipal commercial and industrial operations is prohibited except where it is the only feasible operation and the prior-approval of the Department of Pollution Control and/or the Division of Forestry has been obtained.

Open burning is permitted:

A. "When an emergency exists which requires immediate action to protect the human health and safety."

B. Where a normal collection service is not available and the burning does not create a nuisance.

Any open burning done for research purposes must have prior approval of the Department of Pollution Control, and can only be done under conditions which provide protection of the ambient air against pollution and contaminants.[7]

2. Compacting Refuse in Two Foot Layers

Compaction of solid wastes often proves difficult due to the heterogenous mixture of materials contained in it. The materials contained in solid waste which would normally compact under low pressure are protected by other wastes much like something wrapped in packing material. This effect is known as bridging.

Spreading the wastes in two foot layers with a bulldozer and then running back and forth over it four or five times with the blade up gives good firm compaction. If the slope on which these wastes are spread is at an angle of twenty to thirty degrees they can be well compacted and torn by the bulldozer tracks thus eliminating many voids. When entire loads of brush and yard clippings are received, they should be worked into the bottom of the cell with other wastes on top to increase compaction. See Figure 18.

Bulky items should not be buried in regular portions of the fill to minimize uneven settlement, which might interfere with any future land use. These items which include refrigerators, abandoned cars,

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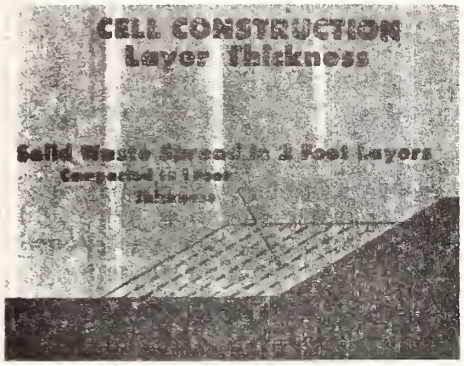
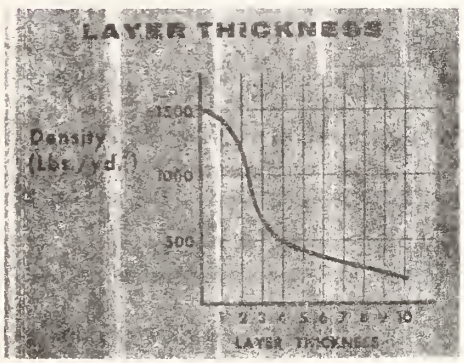
[7] Open Burning and Frost Protection Fires, Chapter 17-5, Dept. of Pollution Control, 1971.

FIGURE 18

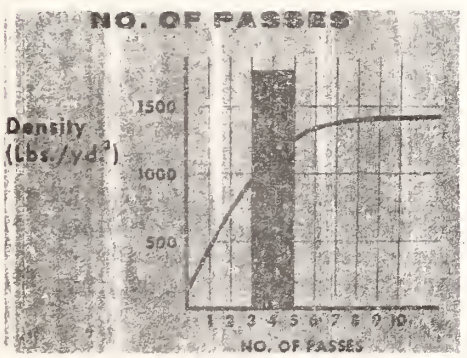
SOLID WASTE COMPACTION



1. This technique requires the initial construction of a 3:1 slope or berm. Refuse is deposited at the base of the slope, spread upward in two foot layers and then compacted to about a one foot thickness.



2. This recommended practice is based on field determinations which show that an optimum density is achieved by using a two foot thickness.



3. To achieve this optimum density requires about five passes over each layer of refuse.

SOURCE: Solid Waste Systems Planning, Solid Waste Management Office, U.S. Environmental Protection Agency, 1972, Cincinnati, Ohio. Sanitary Landfill II, Page I.

washing machines, etc. should be crushed on solid ground first in order to make compaction easier, especially for smaller tractors. These items should also be compacted and covered daily to eliminate vector harborage as well as to keep the site clean.

A method of compacting bulky items which can be considered is a crusher such as the one being used in Charlotte County, Florida. Details on this crusher may be obtained from the Charlotte County Health Department, Punta Gorda, Florida.

3. Limiting Daily Cell Depth to Six Feet

The depth of compacted refuse in a sanitary landfill cell should be limited to six feet, primarily because good compaction cannot be achieved at greater depths. The width of the cell should be kept as narrow (at least the width of two collection vehicles) as is practical but should be able to accommodate all trucks expected to be dumping at the site at any one time, plus the compaction equipment. The length of the cell should be kept within reason and the entire cell covered daily, if not more often. Smaller cells are more stable since more compacted cover material is involved in the overall operation. In the event of underground fires, smaller cells and better compaction limit burning more effectively due to less oxygen being available for combustion. See Figure 19.

4. Daily Cover

A uniform layer of at least six inches of suitable compacted earth cover should be placed over the top, side slopes and the working face

at the end of each working day. Daily cover is necessary to control insects, rodents, blowing litter, water movement and unsightly appearance. Fly emergence is usually prevented by at least six inches of well compacted cover. Cover should be applied to the top and side slopes as construction of the cell progresses, thus leaving only the working face to be covered at the end of the day.

The cover material should be free of large objects (rocks) which would hinder compaction as well as being easily workable and compactable. It should be free of any organic material which would attract rodents and flies, and should be graded to prevent ponding or erosion after placement. It is always adviseable to use as much cover material as possible since as much as 75 percent will seep down into the cell to fill voids created by decomposing refuse.[8] See Figure 19.

Intermediate Cover

Where possible, intermediate cover should be applied after seven days. It serves the same purpose as daily cover with the advantage of better gas and odor control. This cover serves as a better road base for packer trucks especially if they are unloaded at the top of the face. It should be a minimum compacted depth of one foot and will impart better stability and protection to the fill. Periodic surface maintenance where intermediate cover is used will be considerably simplified. See Figure 19.

5. All Weather Access Road

Grades on these roads should not exceed seven percent up hill to protect the equipment. From the public road system to the sanitary

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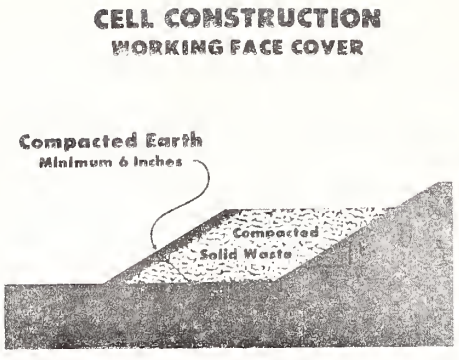
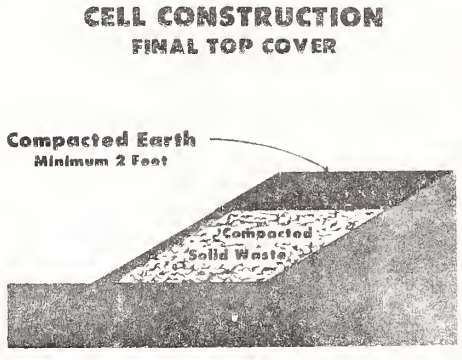
8 Municipal Refuse Disposal, 3rd Ed., (Public Administration Service, APWA Chicago, Illinois, 1970) Page 100.

FIGURE 19

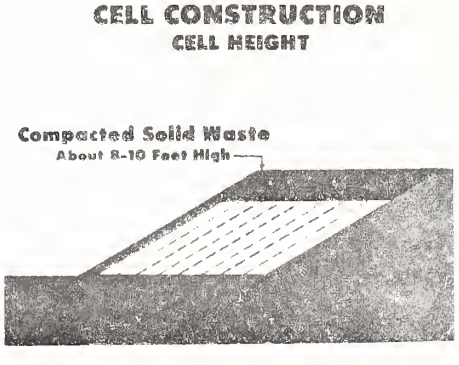
CELL CONSTRUCTION



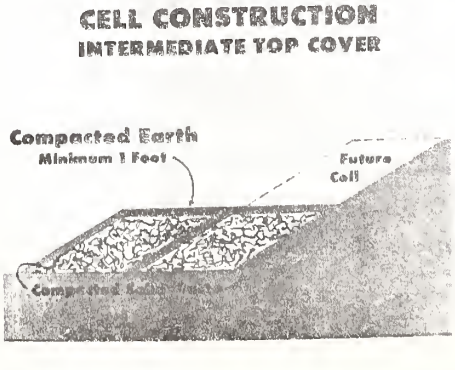
1. Cell construction should continue until the days incoming refuse is compacted in place or the desired length is reached. The cell is then covered with six inches of compacted earth.



2. The top of the cell is covered by no less than two feet of earth. Additional earth cover can be provided to allow for settlement.



3. Overall cell height is measured vertically and is eight to ten feet high including cover. This will vary depending on the operator and the amount of refuse being handled.



4. If additional lifts (layers of cells) are to be added an intermediate cover of one foot of compacted soil must be provided.

SOURCE: Solid Waste Systems Planning, Solid Waste Management Office, U.S. EPA, 1972, Cincinnati, Ohio - Sanitary Landfill, Page 2.

landfill, a permanent road should be constructed with a minimum width of 24 feet to allow two packer trucks to pass safely. In Florida, it is necessary to have a permanent road to a site due to the high average rainfall. This keeps the site accessible at all times.[9]

It is always adviseable to unload packer trucks at the bottom of the cell so that the crawler tractor or compactor may start compacting from the bottom of the cell upward and thus achieve greater volume reduction. Filling should begin at the rear of the site which would permit a semi-permanent road to be constructed from the entrance to the working face. This road would be covered as the working face progresses.

Solid waste disposal is a seven day per week - 365 days per year task. Temporary roads can be made more serviceable in all types of weather by compacting the natural soil and controlling drainage or by covering with gravel, crushed stone, oyster shell, limestone, soil, cement, or asphalt binder.

6. Fly and Rat Control

Rats may occasionally be brought to sanitary landfills by trucks carrying solid waste. These rats usually end up in a landfill cell from which they rarely escape. However, should enough rats escape to become a problem a baiting program under the direction of an exterminator or government rodent control specialist will be required. The public should be informed fully before the program is begun to keep children and pets away from the site. Anticoagulant poisons used over a two to three week period are usually most effective.

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[9] Op. Cit., Pages 46-47.

Specific poisons and insecticides are not listed in this publication due to the ever growing list of those which are restricted.

During the summer months in order to minimize fly problems, it is advisable to apply cover material to the top and sides of the cell and to keep the working face as narrow as practicable. Should the fly problem become too acute an insecticide may have to be used to provide control.

7. Dust and Blowing Paper Control

A sanitary landfill littered by blowing paper and obscured by dust is no better in appearance than an open dump. Failure to control dust and blowing paper leaves the operator of a site justly open to community criticism.

Dust occurs at sanitary landfills during dry portions of the year and is caused by either wind or vehicular traffic. This dust which can be a health hazard to personnel on the site, reduces visibility and creates a nuisance if there are businesses or residences nearby. There are a number of materials which can be used to control dust on the roads. Water, waste oil, soil cement, or some bituminous mixture are all effective controls for roads, but sprinkled or sprayed water is probably the best and most feasible method for the whole site.

Blowing paper is best controlled by keeping the working face as small as possible; using portable fences and natural vegetation; and picking up scattered pieces of paper or plastic everyday. Daily policing of the sanitary landfill site is one of the most important litter control measures.

8. Proper Surface Drainage

Surface water should be diverted away from the sanitary landfill to protect the quality of natural surface waters that would normally flow through the sanitary landfill. Open channels can be used to collect the run-off from areas surrounding the site. Any pipes or channels that are placed on a filled area should be laid in gravel to minimize pipe settlement.

Cover material should be well compacted to induce storm waters collecting on the site to run off rather than seep into completed cells. The surface water which enters the cells increases leachate production and gas generation, which may pose pollution and health problems.

9. No Vertical Leaching

In Florida, vertical leaching is a common problem due to the high water table and the proliferation of highly permeable soils. The concept of the lined sanitary landfill seems to offer great promise in solving this problem. There are a number of liners and liner materials available on the market such as: Bentonite, Hypalon, asphalt, and clay. Clay may appear to be good as a liner, but when it dries it tends to crack and also is not especially common in Florida. If the sanitary landfill is completely lined and sloped to a sump point where the leachate may be collected, there should be little vertical leaching. The leachate should then be pumped into a lined holding pond and treated before discharging. It must be remembered that leachate is many times stronger than municipal sewerage and can be generated over a period of many years.

Due to the high water table, it is possible to visualize that sanitary landfills can be lined and built high above surrounding terrain. In such a system, intermediate cover would be necessary to add increased stability to the sanitary landfill.

10. Scavenging

Scavenging affects the operation of a sanitary landfill by interferring with the quick, orderly operation of the site and must be prohibited. Scavengers are often so busy searching for seemingly valuable items that they are often unaware of approaching equipment. If equipment operators at the site have to watch out for scavengers, they cannot do a proper job. Items set aside by scavengers do offer rat harborage as well as littering the site. Many items disposed of may have been in contact with individuals who have potentially contagious diseases, and would constitute a health hazard to those coming into physical contact with them. Of course, items such as food wastes, canned or otherwise, insecticides, clothing and items which may or may not be contaminated create a health hazard. Solid waste to many people constitutes an attractive nuisance, and if a private individual is injured at the site, negligence suits may follow.

11. Final Two Foot Earth Cover

Final cover basically serves the same functions as intermediate cover or daily cover except that it must also support plant life. It should be applied in compacted six inch layers to a depth of two feet. Unless intermediate cover isused, the final two foot earth cover should be applied after the completed cell is seven days old. The

two foot final cover can be held until the completed cell is one year old, if enough intermediate cover has been applied. Grading is extremely important and grades should not exceed two to four percent. Water should not be allowed to pond and side slopes should be less than one foot vertical to three feet horizontal to avoid erosion.

During the first five years after completion, most of the settlement due to decomposition takes place. Once a site has been completed, it should be planted with grass and native vegetation; policed to prevent further dumping; and graded to prevent ponding of water, erosion, or cracks due to settlement. The agency in Florida with responsibility for solid waste does not recommend the construction of facilities other than parks or playgrounds on completed sanitary landfills. Should even light buildings be constructed on the fill, there is the possibility that a water or sewer line could break due to settlement thus increasing moisture in the refuse and in turn increasing decomposition and methane gas generation. Methane gas could travel into buildings and gather in explosive concentrations. It is safe to build parks and playgrounds on properly completed sanitary landfills since there are usually no fully enclosed shelters or extensive water and sewer connections. Parks and playgrounds offer the possibility of raising the community's tax income and since the public receives something which is beautiful and can safely be used, their support of solid waste programs should increase.

HEALTH AND SAFETY NEEDS

The health and safety of the community is directly linked to that of the individuals working at any waste disposal site, particularly

a sanitary landfill, and it is important that the best working conditions be provided. The following items should be provided where possible:

1. Sanitary facilities such as showers, toilets, locker rooms, septic tanks and drain system, and water supply located on undisturbed ground.

2. Fire control facilities such as fire hydrants, water wagons, foam equipment, or stockpiled earth in the event of a fire.

3. Telephone with a list of numbers of the individuals to be contacted in the event of an emergency or a two way radio.

4. First aid kits to provide treatment for injuries.

5. Electricity to provide power for any electrical equipment and lighting.

EQUIPMENT

Sanitary landfilling, as does any proper method of disposal, costs money to obtain a level of rapid efficient disposal. It is at present the best and cheapest means of solid waste disposal. It is important to realize that normally the per/ton cost of operating a sanitary landfill decreases as daily tonnage of wastes disposed increases. In Figure 1, it is of special significance to note that this cost reduction occurs even though the amount of equipment required is increased. This presents a strong argument in favor of regionalized solid waste disposal systems, serving the largest feasible areas with one site, since less equipment is usually required to operate one central site rather than many smaller sites.

The crawler tractor is the workhorse of sanitary landfill operations, due to its tremendous versatility, rugged construction and its durability. It can excavate cover material, compact and cover solid wastes. Because

of the importance of this piece of equipment, it is wise to have a stand-by tractor in reserve or to arrange to borrow one on short notice. When purchasing a crawler, the question of size is of utmost importance. Figure 20 shows sizes related to the quantity of solid wastes to be handled daily. Figure 21 lists the approximate capital costs of equipment and Figure 22 lists some of the available accessories.

The crawler tractor is not the only piece of equipment which can be used to operate a sanitary landfill; however, it is considered the most essential. There are many other pieces of equipment which can be used to complement the operation of the bulldozer. For larger operations, pan scrapers (earth movers), road graders and steelwheeled compactors are often used to good advantage. In Florida, the dragline is well adapted to work in lowlands and can be invaluable for the excavation of and stockpiling of cover material. Figure 23 shows a listing of the various types of equipment available for sanitary landfill operations and their suitability for various jobs on the site.

The following outline must be carefully followed so that a properly designed sanitary landfill will truly be operated as a sanitary landfill:

OPERATIONS OUTLINE

I. Requirements - A sanitary landfill if operated in a manner to protect the public health and safety must provide for:

A. No burning of any wastes

B. Compaction of refuse in two foot layers

C. Limiting daily cell depth to six feet

FIGURE 20

LANDFILL EQUIPMENT NEEDS

Solid Waste Handled (Tons/8 hr)	Crawler Loader		Crawler dozer		Wheel loader	
	Flywheel horsepower	Weight* (lb)	Flywheel horsepower	Weight* (lb)	Flywheel horsepower	Weight* (lb)
0-20	<70	< 20,000	<80	<15,000	<100	<20,000
20-50	70 to 100	20,000 to 25,000	80 to 110	15,000 to 20,000	100 to 120	20,000 to 22,500
50-130	100 to 130	25,000 to 32,500	110 to 130	20,000 to 25,000	120 to 150	22,500 to 27,500
130-250	150 to 190	32,500 to 45,000	150 to 180	30,000 to 35,000	150 to 190	27,500 to 35,000
250-500	combination of machines		250 to 280	47,500 to 52,000	combination of machines	
500-plus	COMBINATION OF MACHINES					

Note: Compiled from assorted promotional material from equipment manufacturers and based on ability of one machine in stated class to spread, compact, and cover within 300 ft of working face.
*Basic weight without bucket, blade, or other accessories.

This figure is from Sanitary Landfill - Design and Operation by Dirk R. Brunner and Daniel J. Keller.

FIGURE 21

MACHINE CAPITAL COST

Machine type	Horsepower	Weight range (lb)	Equipped Machine: Approximate weight* (lb)	Equipped Machine: Approximate Cost+ ($)	Comment
Crawler dozer	80	15,000	19,000	21,000	landfill blade
	110-130	20,000-25,000	32,000	38,000	landfill blade
	250-280	47,500-52,000	67,000	70,000	landfill blade
Crawler loader	70	20,000	23,000	21,000	GPB‡-1 cu yd
	100-130	25,000-32,500	31,000	30,000	GPB -2 cu yd
	100-130	25,000-32,500	32,000	32,000	MPB**-1 3/4 cu
	150-190	32,500-45,000	45,000	46,000	GPB -3 cu yd
	150-190	32,500-45,000	47,000	49,000	MPB - 2 ½ cu yd
Wheel loader	100	20,000	17,000	21,000	GPB-1 3/4 cu yd
	100	20,000	18,000	23,000	MPB-1 ½ cu yd
	120-150	22,500-27,500	23,000	33,000	GPB-4 cu yd
	120-150	22,500-27,500	26,000	36,000	MPB-2 ¼ cu yd

*Basic machine plus engine sidescreens, radiator guards, reversible fan, roll bar, and either a landfill blade, general purpose bucket, or multiple-purpose bucket as noted.

+June, 1970.

‡General-purpose bucket.

**Multiple-purpose bucket.

This figure is from Sanitary Landfill - Design and Operation by Dirk R. Brunner and Daniel J. Keller.

FIGURE 22

RECOMMENDED AND OPTIONAL ACCESSORIES FOR LANDFILL EQUIPMENT

ACCESSORY	DOZERS		LOADERS		LANDFILL
	CRAWLER	WHEEL	TRACK	WHEEL	COMPACTOR
Dozer blade	O*	O	-	-	O
U-blade	O	O	-	-	O
Landfill blade	R+	R	O	O	R
Hydraulic controls	R	R	R	O	R
Rippers	O	-	R	-	-
Engine screens	R	R	R	R	R
Radiator guards-hinged	R	R	R	R	R
Cab or helmet air conditioning	O	O	R	O	O
Ballast weights	O	O	R	R	R
Multiple-purpose bucket	-	-	R	R	-
General-purpose bucket	-	-	O	O	-
Reversible fan	R	R	R	R	R
Steel-guarded tires	-	R	-	R	-
Lift-arm extension	-	-	O	O	-
Cleaner bars	-	-	-	-	R
Roll bars	R	R	R	R	R
Backing warning system	R	R	R	R	R

*O-optional

+R-recommended

The figure is from Sanitary Landfill - Design and Operation by Dirk R. Brunner and Daniel J. Keller.

FIGURE 23

PERFORMANCE CHARACTERISTICS OF LANDFILL EQUIPMENT*+

EQUIPMENT	SOLID WASTE		COVER MATERIAL			
	SPREADING	COMPACTING	EXCAVATING	SPREADING	COMPACTING	HAULING
Crawler dozer	E	G	E	E	G	NA
Crawler loader	G	G	E	G	G	NA
Rubber-tired dozer	E	G	F	G	G	NA
Rubber-tired loader	G	G	F	G	G	NA
Landfill compactor	E	E	P	G	E	NA
Scraper	NA	NA	G	E	NA	E
Dragline	NA	NA	E	F	NA	NA

*Basis of evaluation: Easily workable soil, and cover material haul distance greater than 1,000 ft.
+Rating Key: E-excellent; G-good; F-fair; P-poor; NA-not applicable.

SOURCE: This figure is from Sanitary Landfill - Design and Operation by Dirk R. Brunner and Daniel J. Keller.

D. Six inches of compacted earth cover applied to each new cell daily or more frequently

E. An all weather access road

F. Fly and rat control

G. Control of dust and blowing paper

H. Proper surface drainage to minimize leachate formation, gas generation and to avoid contamination of natural surface waters

I. No vertical leaching to avoid polluting ground water and aquifers

J. No scavenging to protect public health and safety

K. A final two feet of compacted earth cover

II. Aesthetic Considerations - In order that a sanitary landfill be more acceptable to the public, it should be pleasing to three of the five human senses namely - sight, hearing and smell. These factors should be:

A. Fences to control unauthorized access and blowing litter.

B. A thick growth of trees and shrubs surround the site to increase public acceptance of the operation by confining blowing litter to the site; reducing equipment noise; providing a wind break; and beautifying the neighborhood.

C. The all weather access road should have a moderately sharp curve in it to get collection trucks out of sight quickly.

D. An attractive permanent sign to let the public know that this is a permanent site listing the name of the site; present and future use; schedule of fees; and the hours of operation.

E. Landscaping and planting of finished portions of the site to enhance the beauty of it.

SUMMARY

The guidelines presented herein should be closely followed by those having the responsibility for the planning, designing, operating, and administering of solid waste disposal throughout the State of Florida. Proper solid waste disposal throughtout the State would result in an improved environment, better protection of the public health, and a potential for an increased local tax income. No one wants to think about solid waste once it has been placed in the can for the collector, but if improper disposal methods are permitted to continue, the resulting crisis in public health and environmental quality would be catastrophic - physically, financially and aesthetically. Why allow solid waste to bury us - let's give it a decent burial!

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